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Battelle Columbus Labs, Ohio

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POTENTIAL ENVIRONMENTAL IMPACT OF COMPOUNDING AND FABRICATING INDUSTRIES: A PRELIMINARY ASSESSMENT

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FOREWORD

When energy and material resources are extracted, processed, converted, and used, the related pollutional impacts on our environment and even on our health often require that new and increasingly more efficient pollution control methods be used. The Industrial Environmental Research Laboratory - Cincinnati (IERL-Ci) assists in developing and demonstrating new and improved methodologies that will meet these needs both efficiently and economically.

This report, Potential Environmental Impact of Compounding and Fabricating Industries: A Preliminary Assessment, is intended to be an operational guide for the manufacturing processes used in the compounding and fabricating industries.

Much of the information on emissions from manufacturing processes was obtained from related studies by the Environmental Protection Agency. This report presents data which have been generated to allow identification of all processing steps with significant environmental impact and all compounding and fabrication industries where they are applied. It provides a basis for more intensive study to define R&D which is needed for adequate control of major environmental impacts. For further information, contact the Industrial Pollution Control Division, IERL-Ci, 45268.

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ABSTRACT

The overall objectives of this research effort were to identify compounding and fabricating industries from a selected number of Standard Industrial Classification codes, and identify the environmental impact resulting from processing steps used by fabrication or compounding industries.

Industries in the United States fall into two basic categories--those that process primary raw material such as iron ore, logs, silica sand, animal hide, etc., and those that fabricate or compound these raw materials into various consumer goods. This report assesses the potential environmental impact of industries in the second category, the compounding and fabricating industries. The basic approach was to classify each industry by type and major unit processes supported, and then to characterize the waste streams produced by the unit processes. Examples of industries that are classified as compounding and fabricating industries are the automobile industry and the surface coatings industry.

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SECTION 1

INTRODUCTION

Industries in the United States fall into two basic categories--those that process primary raw materials such as iron ore, logs, silica sand, animal hide, etc., and those that fabricate or compound materials from primary processes into various consumer goods. This report assesses the potential environmental impact of industries in the second category, the compounding and fabricating industries. The basic approach was to classify each industry by type and major unit processes supported, and then to characterize the waste streams produced by the unit processes.

Specific objectives of the project were:

(1) To identify those industries that manufacture consumer products by fabrication and/or compounding of materials received from the primary processing industries

(2) To identify products or groups of products produced by a definable population of companies

(3) To identify the environmental impacts resulting from processing steps used by compounding or fabrication industries.

Data used in this report were taken from the U.S. Bureau of the Census report series, U.S. Environmental Protection Agency (EPA) development documents for effluent limitation guidelines and standard of performance for various point-source categories, and other EPA documents. Some investigators of these industrial groupings have either worked in or visited many of the firms within these categories. Therefore, their conclusions are the result of personal observations over the years.

Because of the preliminary nature of this study and the limited resources and lack of readily available data, all industries were not studied in the same depth.

Listed below are the Standard Industrial Classification (SIC) categories that were reviewed to identify compounding and fabricating industries. These categories were provided to the contractor in the scope of work.

245-Wood buildings and mobile homes
25-Furniture and fixtures
264-Converted paper and paperboard boxes (except containers)

27-Printing, publishing, and allied services
2834-Pharmaceutical preparations
284-Soap, detergents, cleaning preparations, perfumes, etc.
285-Paint, varnish, lacquer, enamels, and allied products
2891-Adhesives and sealants
2893-Printing ink
2899-Chemicals and chemical preparations n.e.c.
2952-Asphalt felts and coatings
30-Rubber and miscellaneous plastics products
31-Leather and leather products
323-Glass products made of purchase glass
3271-Concrete block and brick
3273-Ready-mix concrete
329-Abrasive, asbestos, miscellaneous nonmetallic mineral products
34-Fabricated metal products (except machinery and transportation equipment)
35-Machinery except electrical
36-Electrical and electronic machinery
37-Transportation equipment
38-Measuring, analyzing, and controlling instruments; photographic, medical and optical goods; watches and clocks
391-Jewelry, silverware, plated ware
393-Musical instruments
394-Toys, etc., sporting goods
395-Pens, pencils, and other office and artist supplies
396-Costume jewelry, etc
399-Miscellaneous (brooms, signs, caskets, linoleum)

APPROACH

As a first step the products in the SIC codes were assessed. A study was made of the character of the population of companies producing them, the economic importance of the primary products, the degree to which products were unique to establishments reporting in each SIC category (specialization ratio), the degree to which the principal products were made by establishments associated with other SIC industry categories (coverage ratio) and the degree to which the companies making the products employed similar processes and used similar raw materials. A first attempt then was made to identify real world industries involved in the production of compounded and fabricated products associated with the assigned SIC groups. This list of industries is included as Appendix A for future use in analysis of this category of industries.

For purposes of present analyses the assigned codes were divided into 15 categories for convenience in analysis of economic importance, manufacturing operations, and waste streams associated with each category. These categories and associated SIC codes are listed below

1. Wood buildings and mobile homes (SIC 245)

2. Furniture and fixtures (SIC 25)

3. Converted paper products (SIC 264)
4. Printed products (SIC 27)
5. Compounded organic products (SIC 2834, 284, 285, 2891, 2893, 2899)
6. Rubber and miscellaneous plastic products (SIC 30)
7. Leather goods (SIC 31)
8. Flexible roofing, flooring, and paving products (SIC 2851, 2952, 3996, 3292)
9. Inorganic mineral products (SIC 3271, 3273, 329)
10. Fabricated metal products (SIC 34)
11. Machinery, except electrical products (SIC 35)
12. Electrical and electronic machines (SIC 36)
13. Transportation equipment (SIC 37)
14. Measuring, analyzing, and controlling instruments: photographic, medical, and optical goods; watches and clocks (SIC 38)
15. Miscellaneous manufacturing industry (SIC 39)

Generally, the above-mentioned product groups conform to the 2- or 3-digit SIC census data. However, asphalt floor tile and vinyl asbestos tile (3292) and hard floor covering (3996) were assigned to flexible roofing, flooring, and paving products; the other products in SIC 3292 are studied under inorganic mineral products.

Given for each product group are descriptions of the industry, products, and raw materials, a flow diagram of a representative product, and a discussion of the environmental impact of the waste streams. On each flow diagram, flags are used to indicate which waste stream (air, water, or solid) is affected by the various manufacturing processes or unit operations.

After development of the list of industries and the establishment of categories for use in the study a search for information on the manufacturing operations and waste streams produced was undertaken for each category. The sources of information included effluent guideline documents and other EPA industry studies as well as information from industry publications and background available from past experience of Battelle personnel.

SECTION 2

CONCLUSIONS

The fabricating and compounding industries include literally thousands of small and large firms competitively engaged in the manufacture of products as diverse as automobiles, generators, aspirins, paints, Christmas-tree lights and microwave ovens. The number of companies and establishments listed in this report were taken from the Census of Manufactures reports. No doubt there is some double counting in the totals, since most establishments produce more than a single product. Nonetheless, these numbers provide some appreciation for the level of magnitude of distinct plants. Generally, all of the products from the fabrication and compounding industries are end products. Many of these products will be used in other manufacturing processes, but they generally will not be consumed as raw products.

Assessing the environmental impact of the many products and manufacturing processes is a formidable task. To make this current report more meaningful as an operational guide, the unit processes identified in the conclusion section of this report express the pollution levels in general terms, i.e., medium to high environmental impact. This comment relates to a general level rather than a diagnostic appraisal of the kinds of compounds making up the pollutants.

Most of the manufacturing processes or unit operations used in the compounding and fabricating industries have a recognized impact on the environment. Listed below are processes having a medium-to-high environmental impact:

Water	Air	Solid
Pickling	Casting	Casting (slag, scrap)
Painting	Pickling	Painting
Lubricating	Lubricating	Machining (chips)
Machining	Hot working	Stamping
Electroplating	Heating for forming	Sheet forming
Baking (coatings)	Heat treating	Injection molding (plastic)
Bonderizing	Welding	Welding (slags)
Washing (detergent)	Torch cutting	Insulating (asbestos)
Assembling	Painting	Electrochemical machining
Heat treatment (salts)	Degreasing	Asphalt batching

Etching (glass and metal)	Solvents for coatings	Woodworking machines (sanders, saws, etc.)
Mixing/blending	Drying ovens (painting)	Molding (rubber)
Paper coating and glazing	Mixing (paints)	Molding (block brick)
	Varnish cooking	

It should be emphasized that many of the solids can be recycled as process scrap, especially the trimmings from metal stamping and machining operations. Scrap plastics and some scrap metal are not valuable enough or in enough quantity to warrant accumulation, segregation, and storage for eventual sale to secondary material processors. Generally, the smaller manufacturing shops will merely dispose of the solid wastes in landfills and/or through scrap dealers, who may in turn dump the waste scrap after salvaging whatever is useful from the aggregated scrap materials. Scrap plastics are sometimes incinerated along with other combustible wastes.

Generally, pollutants associated with the wastewater stream of compounding and fabrication manufacturing plants are: oil, heavy metals, cyanide, suspended solids, alkalis, acids, and organic materials, such as solvents, adhesives, phenols, etc. Solid lubricants from forming operations are usually heavy greases. If separated, these wastes are combustible. Most industrial products that are painted are spray painted. This is done in either a dry booth (with air drawn through a filter) or water-spray booth. The water-spray booth removes about 98 percent of the solid overspray particles from the exhaust gas. This permits the solids of pigments from the painting operation to be recovered and resold as a lower grade pigment. The wastewater contains organic solvents and resins.

The principal volume of plating consists of rack and barrel electroplating of copper, nickel, chromium, and zinc onto ferrous and nonferrous metals and plastics. This part of the plating industry accounts for about two-thirds of all chemicals added to wastewater.

Other electroplating processes involve not only the above metals, but also iron, cadmium, tin, indium, gold, silver, and platinum. The principal pollutants associated with electroplating are:

- Heavy metals
- Cyanide salts
- Alkalis
- Acids
- Oil and grease
- Phosphates
- Suspended solids
- COD
- BOD
- Color

Generally, pollutants entering the air waste stream are hydrocarbons from the painting, printing, blending, or mixing operations, degreasing operations, and rubber and plastics processing. However, solid particles enter the atmosphere from grinding, polishing, buffing, mixing, and blending operations. Welding, brazing, and soldering operations emit fumes into the atmosphere, but these fumes tend to be localized within the plant area.

Of the toxic water pollutants listed in Section 307 Federal Water Pollution Control Act PL 92-500 only polychlorinated biphenyls (PCBs) is noted in this study. However, several potentially objectionable materials that are discharged include lead from paint, battery, and rubber fabricating plants, chromium from chromic acid cleaning solutions, organic solvents from degreasing operations, mercury compounds from paint and instrument manufacturing, phenols from furniture and insulation manufacturing, cyanide from plating processes and cadmium from coating processes.

Of the hazardous air pollutants listed in Section 112 of the Clean Air Act only asbestos and vinyl chloride are noted in this study. Other potentially hazardous materials discharged into the atmosphere include volatilized hydrocarbons and chlorinated hydrocarbons. Sources of volatilized hydrocarbons emissions include paint bake ovens, manufacture of rubber and plastic products, and printing drying ovens. A major source of chlorinated hydrocarbons identified in this study is metal degreasing operations. The two most frequently used chlorinated hydrocarbons are trichloroethylene and methyl chloroform - both are considered to be toxic compounds. At present the emission information available for assessing the impacts from the important manufacturing operations is for the most part strictly qualitative. The data on composition of waste streams, number of sources, population of people impacted, and the like are very scarce. It is apparent, however, from the general character of emissions and from the number of known problems which have been identified, that the environmental impacts associated with the compounding and fabrication industries need to be understood and better controlled. It is believed that this study has laid a foundation for a future program consisting in large part of field investigations, which will firmly define environmental needs.

SECTION 3

RECOMMENDATIONS

It is recommended that the unit processes presented in Section 2 and the industries presented in Appendix A be used as a basis for design of a program to define R&D needed to control the environmental impacts associated with the compounding and fabrication industries in detail. A study involving two concurrent phases is visualized.

One phase should involve collection mostly in the field of information on all of the unit operations which have been identified as having medium to high environmental impact. The objective would be to define the nature of the equipment variations, and variations in input and output matrixes, and collect quantitative data on emissions. All factors needed to define the nature of the control problem would be examined. Vendors of equipment and materials would be contacted for information on products, and users of equipment would be contacted in a field inspection program which would lead to collection of all available data and define possible needs for sampling and analyses of emissions.

In the first phase, an attempt should be made to define the general nature of all variations for each manufacturing operation. This would lead to development of a data base to identify problems needing in-depth study, eg., significant air emissions have been identified from the unit fabrication methods employed by the plastics industry. It is known, for example, that the resin-supplying industry has adjusted the rate of free vinyl chloride monomer in PVC to permit safe handling. However, specific problems may exist which would require additional studies to assess their importance. Examples of these "potential" problems might be the nitrile blowing agents used in some foam manufacture and the isocyanates used in some blow molding and spray application of urethane. In-depth studies should concentrate on specific materials such as, for example, styrene and acrylonitrile. Both of these materials give off sufficient odor during processing to attest to their volatility. However, it is assumed that styrene is held to acceptable concentrations and no problems exist with acrylonitrile.

A second concurrent phase should involve inspection of selected plant sites associated with the industries listed in Appendix A. Key industries, representative of all classes of industries would be selected e.g., construction equipment might be studied to define problems associated with many of the equipment industries which have been identified. Selection of industries and plant sites for visitations would be done in a way that permitted maximum coverage with a minimum amount of travel.

SECTION 4

RESEARCH APPROACH

To accomplish the objectives of this study, the following methodology was used:

(1) A literature search was conducted to identify and obtain the necessary documents.

(2) Standard Industrial Classification Code (SIC) categories were examined to identify candidate industries involved in producing consumer products by compounding and fabrication.

(3) After industries were defined for consideration, information sources such as the Census of Manufactures and trade associations were used to verify the various industrial classifications.

(4) Unit operations and manufacturing processes were analyzed for each industry. Waste streams were identified as to their impact or potential impact on the environment.

The literature search emphasized the identification of manufacturing processes/unit operations, and identification of various waste streams that have an impact on the environment. The products involved in the various categories were all compounded or fabricated items. Where this was not the case, products involving other processing steps were ignored.

Industries were analyzed to verify that products were produced by a definable population of companies that were engaged competitively in the production of similar or identical product lines.

SECTION 5

RESULTS AND DISCUSSION

WOOD BUILDINGS AND MOBILE HOMES

This industry includes establishments that are primarily engaged in manufacturing mobile homes and prefabricated wood buildings and components for same.

Mobile Homes

This industry includes establishments primarily engaged in the manufacture of mobile homes. These homes are generally over 10.67 meters (35 feet) long, at least 2.44 meters (8 feet) wide, do not have facilities for storage of water or waste, and are equipped with wheels. In addition to being used as residential homes, these units can be used as offices and classrooms. Shipments of mobile homes in 1972 represented 99 percent of the industry total product shipments, while secondary shipment consisted mainly of prefabricated wood buildings. In 1972 there were 352 companies operating 682 plants in the United States. They employed 72,200 people, purchased materials valued at $2.227 billion, and shipped products valued at $3.252 billion.(1)

Manufacturing Processes--

Information on the manufacturing processes and unit operations in the mobile home industry is not readily available. The major input materials are steel, aluminum, lumber, and plywood. The following major processes are used in the manufacture of mobile homes: sawing or cutting aluminum, lumber, and plywood; finishing and painting of components; and assembling. Figure 1 shows a simple flow diagram of the manufacturing process.

Waste Streams--

Woodworking machines such as saws, planers, and sanders produce substantial amounts of solid waste.(2) These wastes are generally exhausted to air pollution control devices. Also solid waste is generated from cutting or sawing of aluminum strips, and painting operations emit hydrocarbons into the atmosphere.

Prefabricated Wood Buildings

This industry includes establishments primarily engaged in manufacturing prefabricated wood buildings, sections, and panels. Shipments of prefabri-

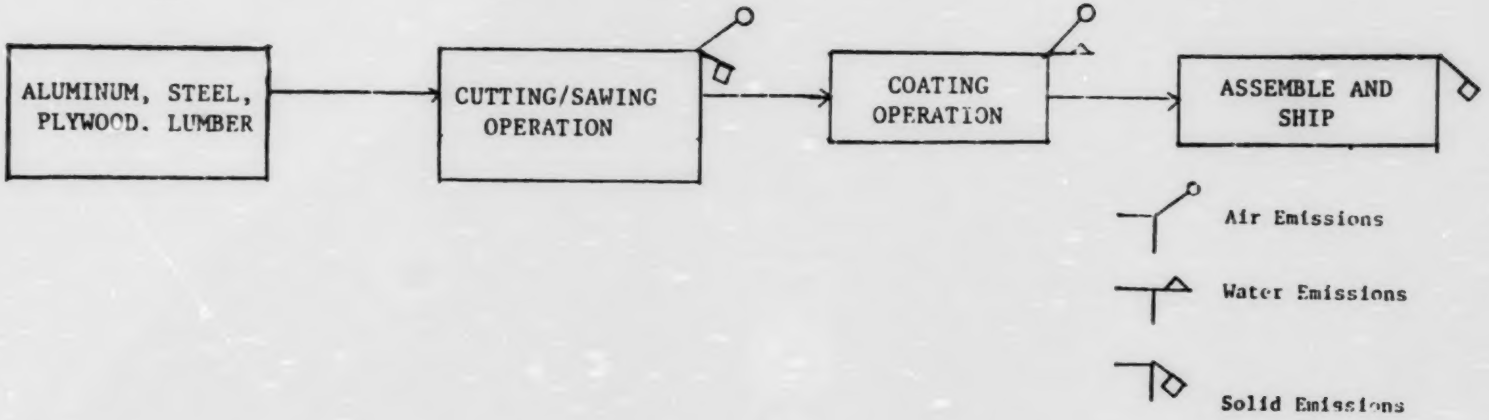
ALUMINUM, STEEL, PLYWOOD. LUMBER
CUTTING/SAWING OPERATION
COATING OPERATION
ASSEMBLE AND SHIP
Air Emissions
Water Emissions
Solid Emissions

FIGURE 1. PROCESS FOR MANUFACTURING MOBILE HOMES.

cated wood buildings represented 97 percent of the industry total shipments in 1972. Establishments that fabricate buildings on the construction site are not included.

The types of prefabricated wood building in this industry are: chicken coops, corn cribs, farm buildings, marinas, and precut houses. In 1972 there were 268 companies operating 315 establishments. They employed 25,500 people, purchased materials valued at $619 million, and shipped products valued at $1.06 billion.(1)

Manufacturing Processes--

The major unit operations or processes in this industry are cutting, sawing, planing, finishing, or coating of the lumber. Major materials that are used in this industry that have an impact on the environment are: rough lumber, plywood, particle board, paint, varnish, lacquers, and enamels. Figure 2 shows a simple diagram of the manufacturing process.

Waste Streams--

Woodworking machines produce large quantities of waste sawdust, shaving and chips that must be removed from the equipment site.(2) Exhaust systems are used with many types of woodworking machines that are capable of producing appreciable sawdust, chips, or shavings by drilling, carving, cutting, routing, turning, sawing, grinding, planing or sanding wood. Woodworking exhaust systems are somewhat unusual in that they are almost always equipped with air-pollution control devices. In addition to the wood waste, hydrocarbons are emitted into the atmosphere from the painting and varnishing of the finish lumber.

FURNITURE AND FIXTURES

This segment of U.S. industry includes all establishments that are primarily engaged in manufacturing household, office, public building, and restaurant furniture. Store and office fixtures are also included. In 1972 there were 9,233 establishments in this industry, employing 462,400 people. They purchased materials valued at $5.342 billion and shipped products valued at $11.23 billion.(1)

A very limited number of firms can supply their own raw materials and form them into furniture. More than 60 percent of the establishments in the furniture industry have less than 20 employees and generate less than $500,000 in annual sales.

Of the 6,000 ± companies which produce furniture, only 250 can be considered major trend-setting factors in the industry. The 10 largest firms represent about 20 percent of the industry sales. North Carolina is the leading furniture production state with 22 percent of the shipments of all household furniture. Metal office furniture production is highly concentrated in the Great Lakes areas.

As might be expected, the manufacture of household furniture dominates

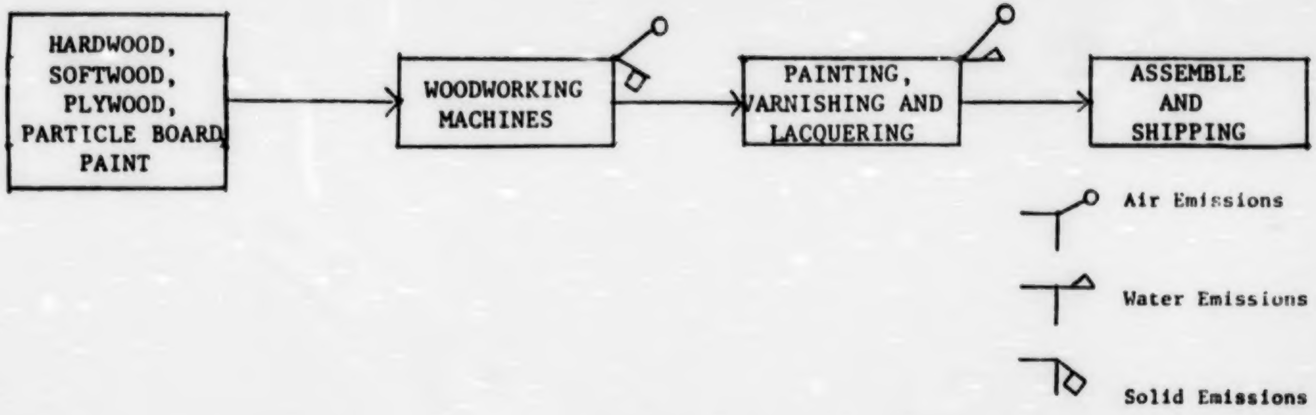
HARDWOOD,
SOFTWOOD,
PLYWOOD,
PARTICLE BOARD
PAINT
WOODWORKING MACHINES
PAINTING, VARNISHING AND LACQUERING
ASSEMBLE AND SHIPPING
Air Emissions
Water Emissions
Solid Emissions

FIGURE 2. PROCESS FOR MANUFACTURING PREFABRICATED WOOD BUILDINGS AND COMPONENTS.

this industry. Establishments that are primarily engaged in manufacturing household furniture represented 59 percent of the total establishments in the industry in 1972, employed 68 percent of the people, spent 67 percent of the money spent for materials, and shipped 63 percent of the dollar value of products. The following four segments represent the bulk of the manufacture of household furniture.

Wood Household Furniture

In 1972, 2348 establishments were primarily engaged in manufacturing wood household furniture. They employed 133,800 people, spent $1,355 billion for materials, and shipped products valued at $2.87 billion.

Upholstered Household Furniture

In 1972, there were 1,308 establishments primarily engaged in manufacturing upholstered household furniture. They employed 92,000 people, spent $1.018 billion for materials, and shipped products valued at $2.105 billion.

Metal Household Furniture

There were 467 establishments in 1972 primarily engaged in manufacturing metal household furniture. They employed 34,400 people, purchased materials valued at $452 million, and shipped products valued at $890 million.

Mattresses and Bedsprings

In 1972, the 978 establishments primarily engaged in manufacturing mattresses and bedsprings employed 31,600 people. They purchased materials valued at $570 million and shipped products valued at $1.048 billion.

Other Segments

Other segments of the furniture and fixtures industry are significantly smaller than the preceding four. Other segments include manufacturers of radio and TV cabinets, wood and metal office furniture, furniture for public buildings, wood and metal partitions and office and store fixtures, drapery hardware and blinds and shades, and furniture and fixtures not elsewhere classified.

Wood Furniture

Manufacturing Processes--

More than 70 percent of the furniture constructed in the United States employs wood as the main material of construction. Approximately 20 percent utilizes metals for construction frames. The increased use of pressboard and hardboards in quality furniture is expected to increase the total consumption of wood.

The production of wood furniture can be simply described as prefinishing, finishing, and packaging operations. Prefinishing includes operations to size, cut, bend, glue, metal fix, join veneer, and laminate. The moisture content of the wood is also controlled. Finishing operations include wood graining, bleaching, staining, sealing, topcoating, and polishing.

Figure 3 shows the typical operations in a wood furniture plant. Many of the operations require skilled craftsmen and are labor intensive.

Waste Streams--

The cutting and shaping operations produce solid wastes in the form of sawdust and wood scraps. Part of this waste may initially be airborne, and is removed from the air by filters or baghouse facilities.

In the wood furniture assembly business the effluents from the finishing and laundry booths are identified as the major unit operations that impact the environment via water, air, and sludge media. To be specific, the wood preserving, painting, polishing, and metal plating utilize chemical forms that many prominent sources consider to be toxic materials. The numerous laundry operations generate copious volumes of varying degrees of degradable detergents, emulsifiers, and soaking agents. The effluent from the laundry operations may further contain dyes, fungicides and, of course, the industrial chemicals that were being absorbed by the rags or upholstery fabrics.

The following is a listing of compounds that are expected to be found in the sludges and volatilizing or evaporating within the confines of a furniture plant. It is understood that many of these wastes have been blended or otherwise mixed and may be reduced, combined, or altered in many ways:

- Varnishes
- Shellacs
- Lacquers
- Linseed oils
- Tung oil
- Epoxies
- Polyurethane
- Phenolics
- Melamines
- Phenol-formaldehyde
- Hydrogen peroxide
- Sodium hydroxide
- Alcohol (isopropyl)
- Ammonia
- Titanium dioxide
- Polyvinyl acetate
- Carbon black
- Aliphatic hydrocarbons
- Chlorinated hydrocarbons
- Solvents
- Benzene
- Toluene
- Xylene
- Naphthas
- Resins
- Ketones

Non-Wood Furniture

Manufacturing Processes--

Metals and plastics are used primarily in commercial and institutional furniture production. Figure 4 shows a simplified diagram of the assembly of non-wood furniture.

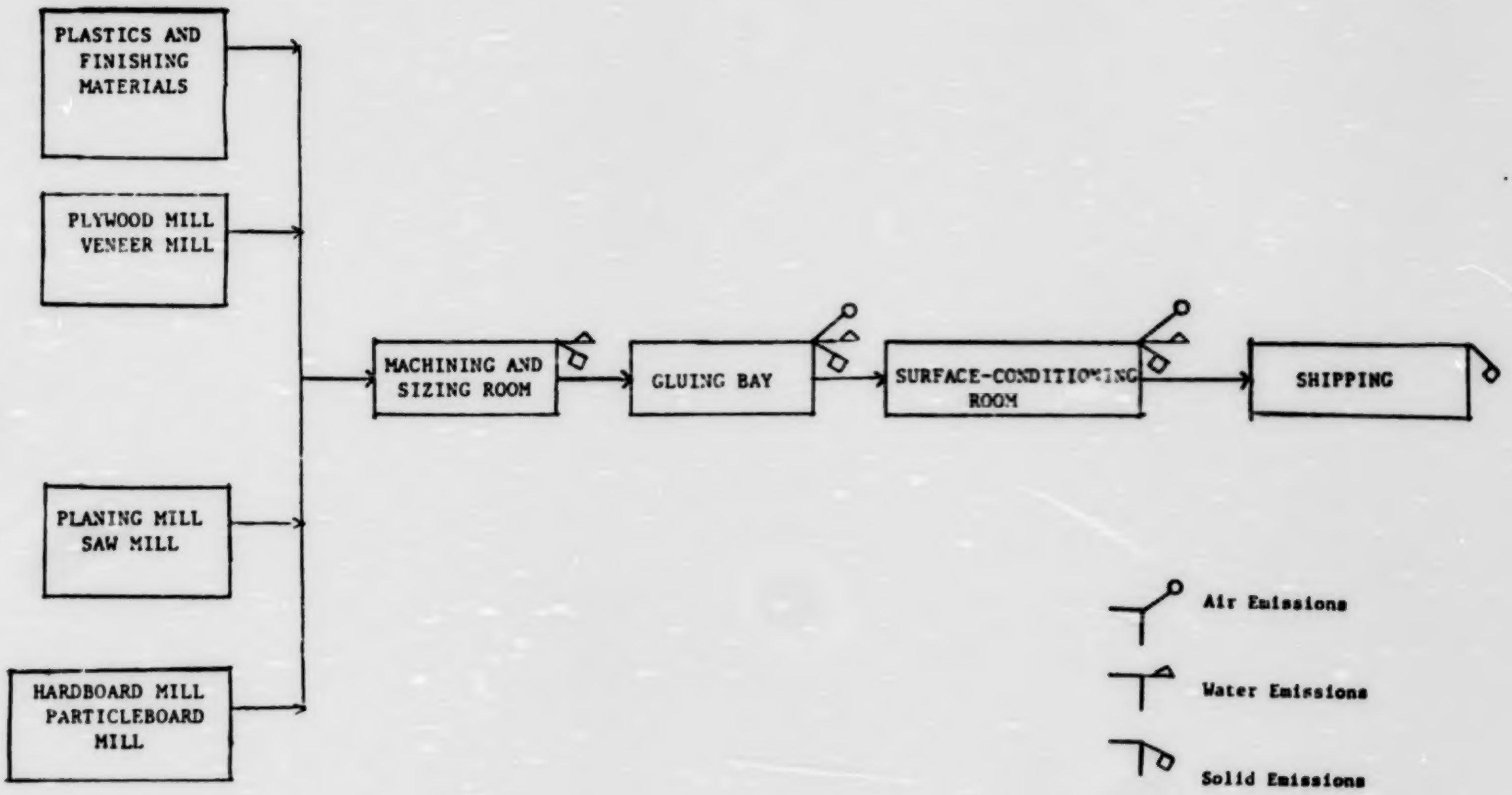
PLASTICS AND FINISHING MATERIALS
PLYWOOD MILL VENEER MILL
PLANING MILL SAW MILL
HARDBOARD MILL PARTICLEBOARD MILL
MACHINING AND SIZING ROOM
GLUING BAY
SURFACE-CONDITIONING ROOM
SHIPPING
Air Emissions
Water Emissions
Solid Emissions

FIGURE 3. BASIC SCHEMATIC FOR A LARGE FURNITURE PLANT.

Reproduced from best available copy.

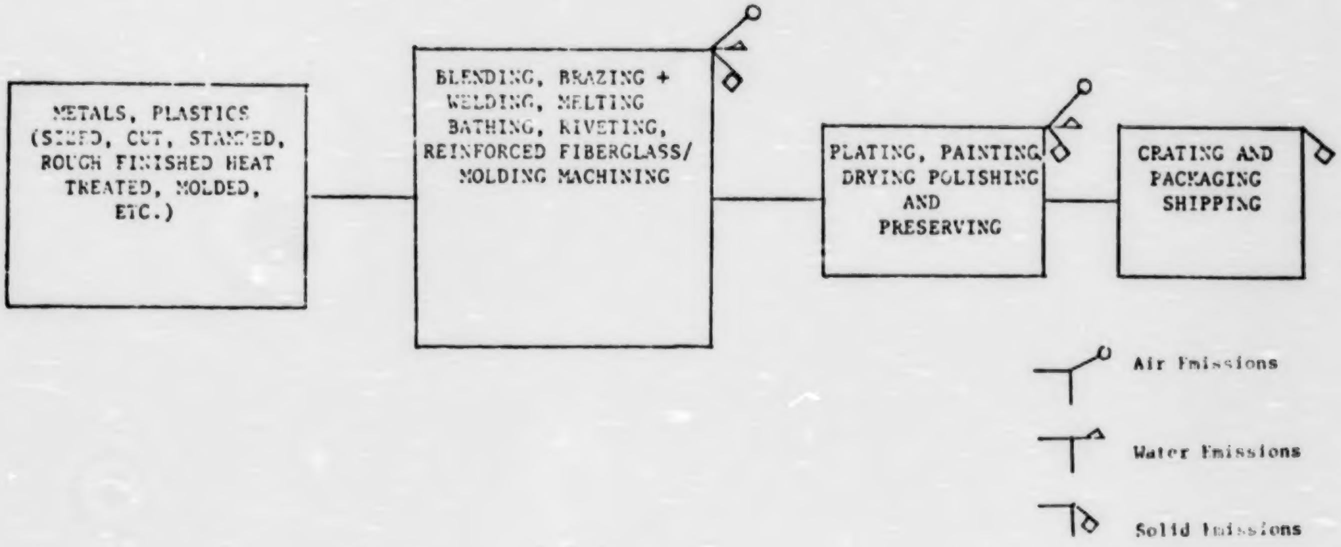
METALS, PLASTICS (SIZED, CUT, STAMPED, ROUGH FINISHED HEAT TREATED, MOLDED, ETC.)
BLENDING, BRAZING + WELDING, MELTING BATHING, RIVETING, REINFORCED FIBERGLASS/ MOLDING MACHINING
PLATING, PAINTING DRYING POLISHING AND PRESERVING
CRATING AND PACKAGING SHIPPING
Air Emissions
Water Emissions
Solid Emissions

FIGURE 4. SIMPLIFIED NON-WOOD FURNITURE ASSEMBLY.

Waste Streams--

Solid wastes arise from metal and plastic scrap and from packaging materials. Plating operations give rise to water pollutants, as do some metal-forming operations. Gaseous effluents result from painting and drying operations.

CONVERTED PAPER PRODUCTS

This industry includes establishments that are primarily engaged in manufacturing fabricated paper products. Of primary importance to this industry is that all products are made from purchased paper or board. As such, the environmental problems associated with producing raw paper are not considered in this section. Environmental considerations are mostly limited to paper waste, printing and coating materials, and glue.

Two major literature sources were used extensively for this analysis. Measures of industry structure were taken from Industrial Marketing Guide(3), a recognized reference on the paper industry. Descriptions of unit operations and environmental considerations were liberally excerpted from an EPA Development Document.(4)

In the development document mentioned above, the authors note that the only process group in this industry that has serious environmental considerations is paper coating and glazing. The remaining industries are low-priority industries based on plant visits conducted by EPA. Therefore, in the report that follows, the environmental considerations noted are potential rather than actual.

Paper Coating and Glazing

This industry is composed of establishments primarily engaged in manufacturing coated, glazed, or varnished paper from purchased paper. Also included in this industry are establishments engaged in manufacturing pressure-sensitive tape with backing of any material other than rubber. Common products in this category include cellophane (e.g., Scotch) tape, flypaper, litmus paper, premoistened towelettes, and waxed paper.

This industry is composed of 426 establishments operated by 341 companies. In 1972 the four largest companies produced 26 percent of the shipments valued. The 50 largest companies accounted for 77 percent of the value of shipments.

Manufacturing Processes--

The processes used in this industry are distinguished by applying a coating to the raw product, often leaving the shape unaffected. Figure 5 illustrates the major processing steps in this industry. The primary distinction between the many types of processes and products is the type of coating used.

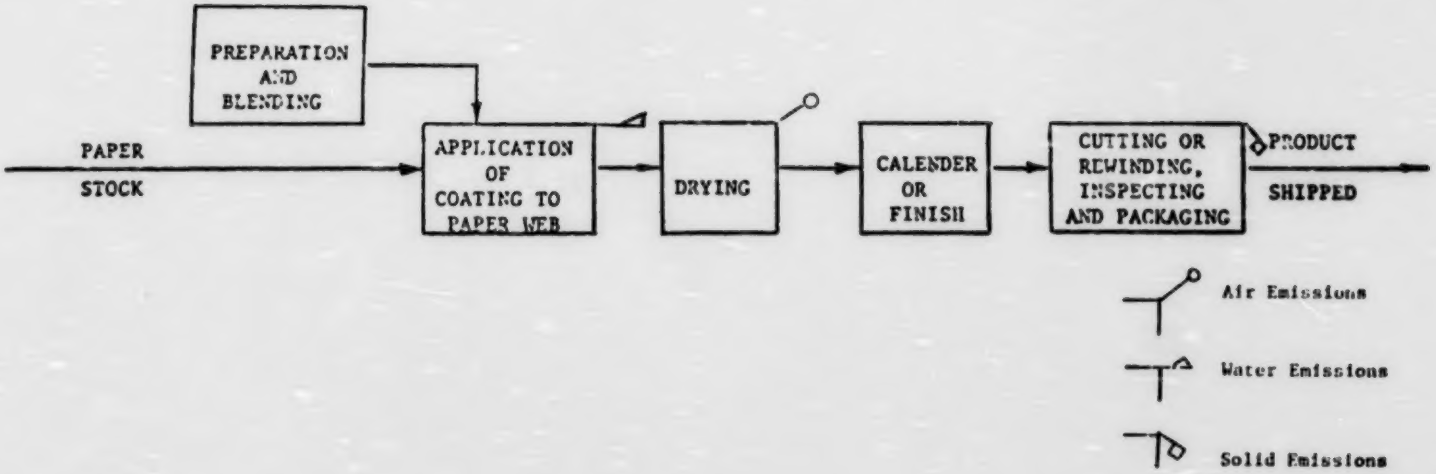
PREPARATION AND BLENDING
PAPER STOCK
APPLICATION OF COATING TO PAPER WEB
DRYING
CALENDER OR FINISH
CUTTING OR REWINDING, INSPECTING AND PACKAGING
PRODUCT SHIPPED
Air Emissions
Water Emissions
Solid Emissions

FIGURE 5. PAPER COATING AND GLAZING.

There are three major coating types used in this industry: aqueous-base, solvent-base, and hot-melt. The aqueous base is the cheapest coating because water acts as the carrier. Water is mixed with adhesives, pigments, and various additives to make the coating. Solvent-base coatings use organic solvents (e.g., ester, alcohols) as the carrier. These coatings are less likely to produce water pollution because they can be readily recovered. The hot-melt coating system uses similar mixing materials as solvent-base. The coating is applied in molten form rather than as a solution or dispersion.

Coating mixtures are prepared in batches and applied to the paper through a variety of methods. The paper may be dipped, casted, rolled, brushed, sprayed, etc. Following this the coated paper is dried and finished. Finishing may involve "ironing" and/or the application of embossing rolls for designs. The final steps are cutting or rewinding, inspecting, packing, and shipping.

Waste Streams--

According to the EPA(4) there do not appear to be major environmental problems in this industry. Wastewaters are described as low in volume but possibly concentrated in nature. The general industry practice is discharge to municipal sewers. Complete control of effluents is indicated as possible.

There is the possibility of air pollution from the driers and solid waste generation from several operations. Further investigation is required to further document the potential problems. Nonetheless, the potential for water pollution appears to be more critical than that for either air or solid waste.

Envelopes

The manufacture of envelopes is a medium-sized paper conversion industry with shipments in 1972 of $587.7 million. About 178 companies operate 247 different establishments. It is not as highly concentrated as others, even though the 50 largest firms account for 81 percent of industry shipments.

Manufacturing Processes--

As shown in Figure 6, paper is brought into the plant in rolls, cut into sheets, and then die-cut in an envelope press. The envelopes are either printed or left plain, and window punching is optional. The envelopes go through a folding and gluing operation, then are packaged and shipped.

Waste Streams--

Possible environmental impacts could occur from wastepaper, printing fluids, and glue waste.

Non-Textile Bags

This category includes both heavy duty bags (for cement, dog food, etc.) and grocery type bags. Over 460 companies produce bags at 583 establishments.

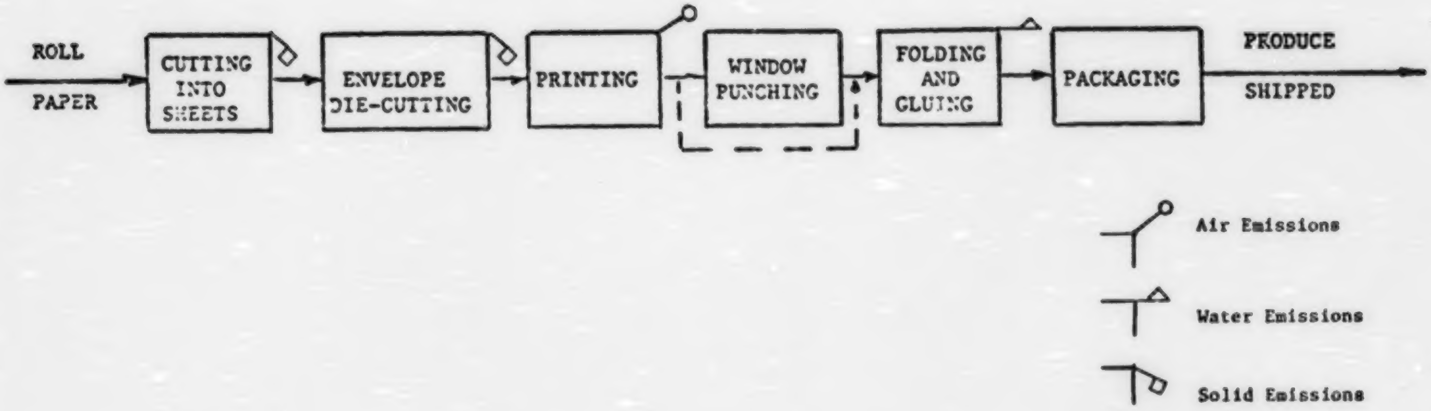
ROLL
PAPER
CUTTING INTO SHEETS
ENVELOPE DIE-CUTTING
PRINTING
WINDOW PUNCHING
FOLDING AND GLUING
PACKAGING
PRODUCE
SHIPPED
Air Emissions
Water Emissions
Solid Emissions

FIGURE 6. ENVELOPES.

This is one of the larger converted paper industries with 1972 shipments totalling $1.8 billion.

Manufacturing Processes--

One of two major processes may be employed in this industry, as shown in Figure 7. In the first process, roll paper is printed, glued and subjected to shrink-oven operations (plastic covering, packaging.) In another, rolls of paper are passed through a bag machine (cut to tube length, glued and sewn, with shrink-oven operations optional before shipping.)

Waste Streams--

There is potential environmental impact from paper waste, printing fluids, and glue waste.

Die-Cut Paper and Paperboard and Cardboard

This industry manufactures products such as postcards, filing folders, and stencil cards. Most of the products are relatively expensive in relation to much of the paper industry. In 1972, industry shipments totalled $646.6 million from 309 companies and 374 establishments. The 50 largest companies account for 80 percent of industry output.

Manufacturing Processes--

In making tabulating cards and special forms, roll paper is slit, printed (letterpress or offset) and die cut to form standard cards. They are then packaged (which requires some gluing) and shipped. Special forms require some assembling and gluing before they are packaged.

To make single-ply business forms, roll paper is slit, printed, folded or rewound, and packaged. For multiple plies, the forms are collated (carbon insertion and gluing) before they are packaged. Figure 8 illustrates these processes.

Waste Streams--

Environmental considerations include wastepaper, printing fluids, and glue.

Pressed and Molded Pulp Goods

This is a highly concentrated but small industry. Industry products include papier-maché articles, egg cartons, etc. Only 32 companies are in this industry, operating 49 establishments. The four largest companies account for 75 percent of industry shipments. Figure 9 illustrates the process in this industry.

Manufacturing Processes--

In general, processing consists of printing paper stock (if necessary),

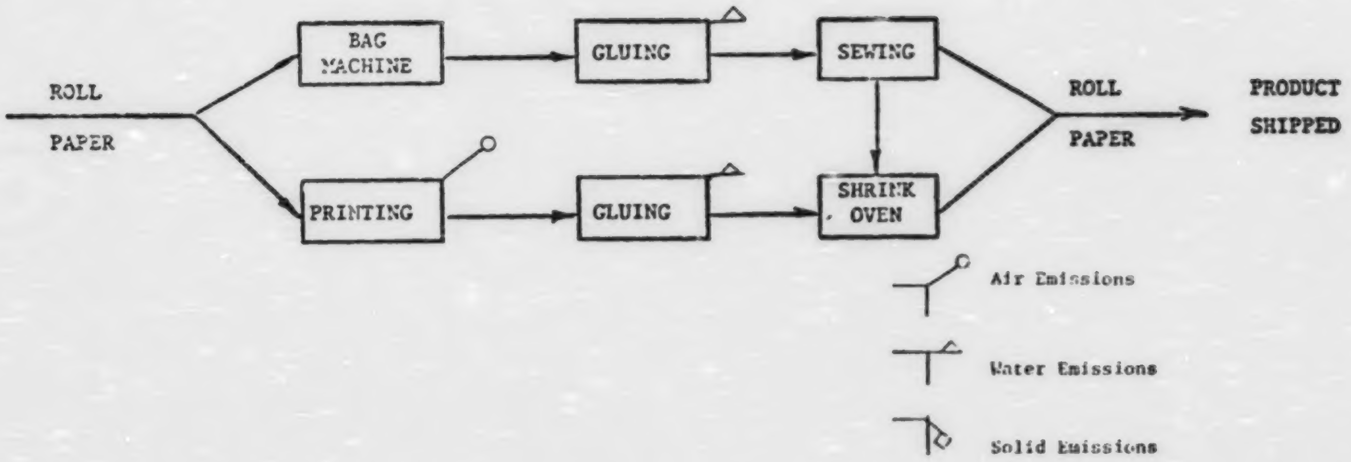
ROLL
PAPER
BAG MACHINE
PRINTING
GLUING
GLUING
SEWING
SHRINK OVEN
ROLL
PAPER
PRODUCT
SHIPPED
Air Emissions
Water Emissions
Solid Emissions

FIGURE 7. BAGS, EXCEPT TEXTILE BAGS.

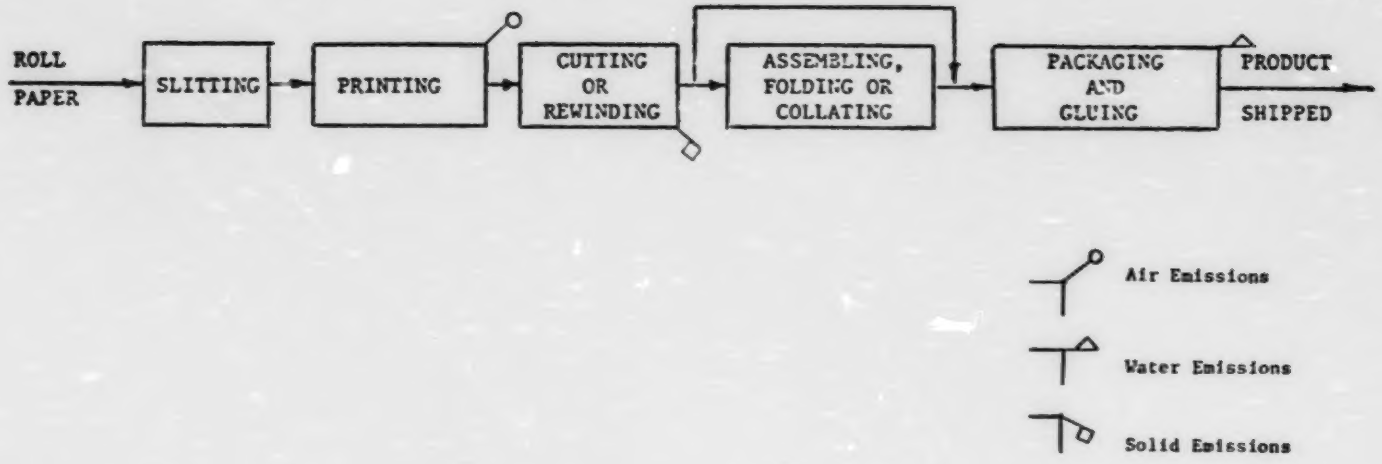
ROLL
PAPER
SLITTING
PRINTING
CUTTING OR REWINDING
ASSEMBLING, FOLDING OR COLLATING
PACKAGING AND GLUING
PRODUCT
SHIPPED
Air Emissions
Water Emissions
Solid Emissions

FIGURE 8. DIE-CUT PAPER AND PAPERBOARD AND CARDBOARD.

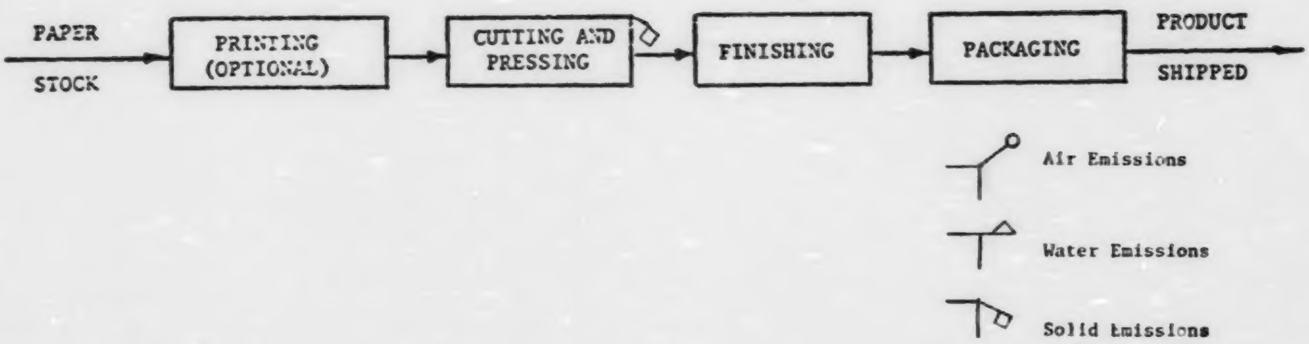
PAPER
STOCK
PRINTING
(OPTIONAL)
CUTTING AND
PRESSING
FINISHING
PACKAGING
PRODUCT
SHIPPED
Air Emissions
Water Emissions
Solid Emissions

FIGURE 9. PRESSED AND MOLDED PULP GOODS.

pressing and cutting, finishing (lining, coating, etc.) and packaging.

Waste Streams--

Environmental impacts include coatings (see paper coating and glazing), wastepaper, printing fluids, and glue.

Sanitary Paper Products

This is a highly concentrated industry, including consumer use items such as toilet tissue, paper napkins, and disposable diapers. The four largest companies account for 65 percent of industry shipments valued at almost $2.0 billion in 1972. Only 72 companies operate in this large industry.

Manufacturing Processes--

Different types of paper are purchased in the form of jumbo rolls. They are unwound, embossed (towels and napkins), and printed, if necessary. Paper stock for towels and bathroom tissue is perforated, rewound and packaged, which requires some gluing. Napkins, tissues, and industrial wipes are cut and folded after the printing operation and then packaged. For sanitary napkins and diapers, the process is essentially a gluing operation to adhere the fluffy pulp layers to the liners. Figure 10 describes these operations.

Waste Streams--

Environmental considerations include paper waste, glue, and printing materials.

Stationary Products Industry

The stationary products industry produces tablets, desk pads, etc. Industry shipments in 1972 totaled $422.6 million. The 50 largest companies accounted for 64 percent of industry shipments.

Manufacturing Processes--

Figure 11 describes the operations in this industry. Roll paper is ruled (tablets) or printed (stationary), followed by cutting. All types of printing are utilized, including some photography. Covers are added, and the items are bound by stitching, gluing, or sewing. For plain stationary, roll paper is simply cut and packaged.

Waste Streams--

Environmental considerations include wastepaper, printing, and photographic materials and glue.

Converted Paper Products, n.e.c.*

The converted paper products n.e.c. industry produces diverse items such

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* n.e.c. = not elsewhere classified.

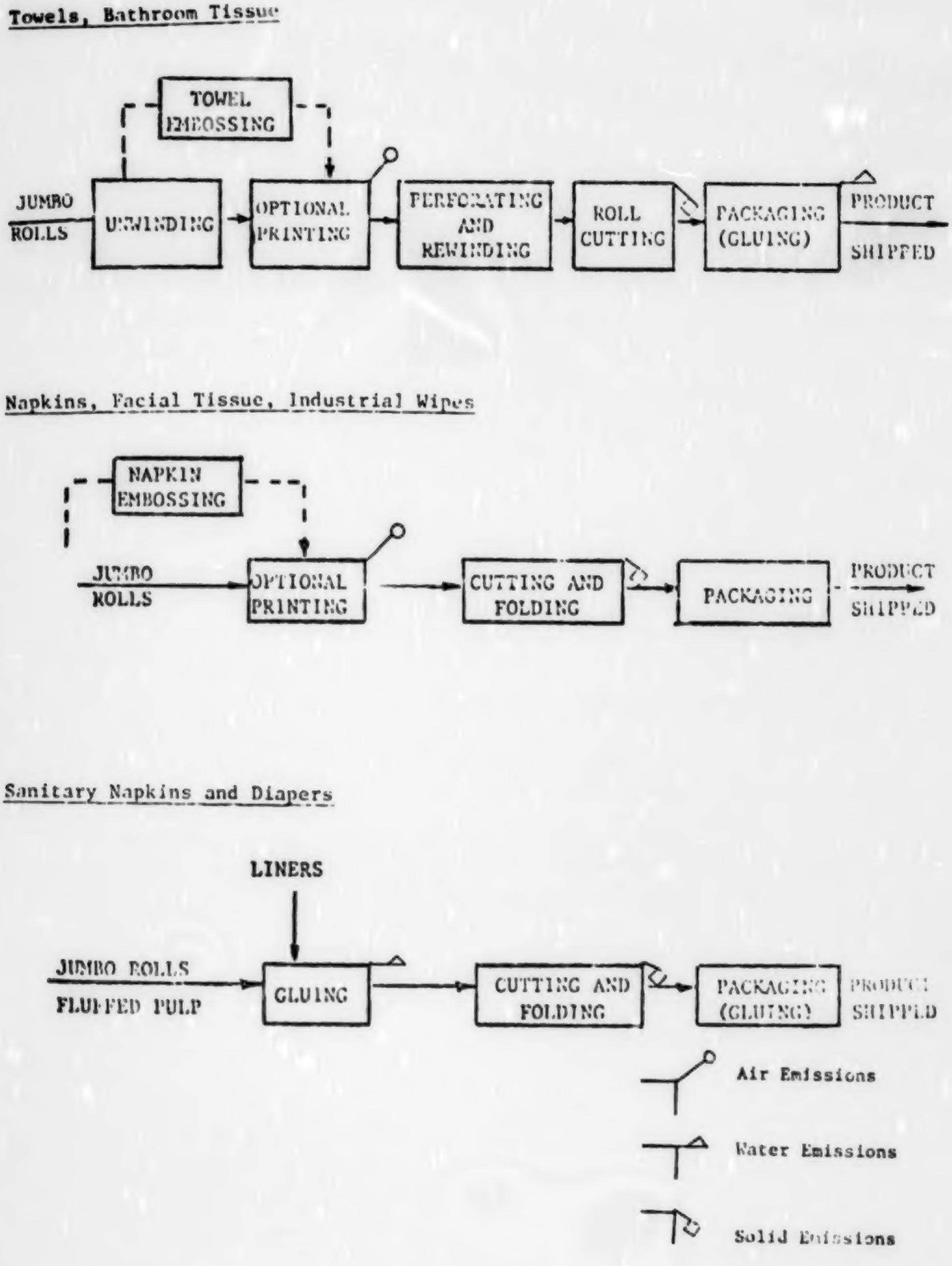
Towels, Bathroom Tissue
TOWEL EMBOSSING
JUMBO ROLLS
UNWINDING
OPTIONAL PRINTING
PERFORATING AND REWINDING
ROLL CUTTING
PACKAGING (GLUING)
PRODUCT SHIPPED
Napkins, Facial Tissue, Industrial Wipes
NAPKIN EMBOSSING
JUMBO ROLLS
OPTIONAL PRINTING
CUTTING AND FOLDING
PACKAGING
PRODUCT SHIPPED
Sanitary Napkins and Diapers
LINERS
JUMBO ROLLS
FLUFFED PULP
GLUING
CUTTING AND FOLDING
PACKAGING (GLUING)
PRODUCT SHIPPED
Air Emissions
Water Emissions
Solid Emissions

FIGURE 10. SANITARY PAPER PRODUCTS.

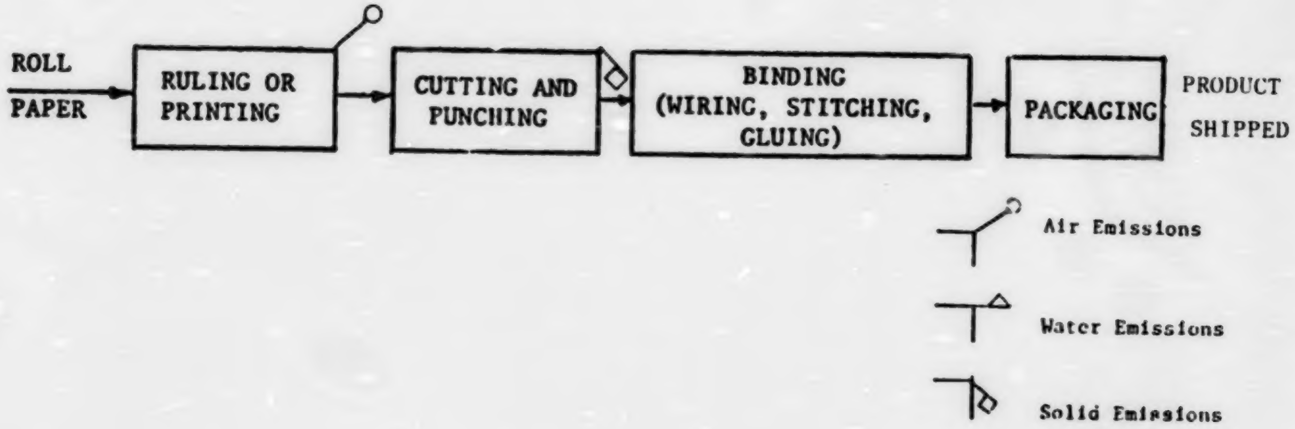
ROLL
PAPER
RULING OR PRINTING
CUTTING AND PUNCHING
BINDING (WIRING, STITCHING, GLUING)
PACKAGING
PRODUCT SHIPPED
Air Emissions
Water Emissions
Solid Emissions

FIGURE 11. PRODUCTION OF STATIONARY, TABLETS, AND RELATED PRODUCTS.

as confetti, wall paper, and crepe paper. Industry shipments totaled $285 million in 1972. Because of the wide range of products, industry concentration is low.

Manufacturing Processes--

Because of the diverse number of products in this industry, no process diagram is immediately available. In general, this industry does not differ from others in the converted paper products industry. Purchased paper is cut, printed or dyed (optional), glued and folded, and packaged for shipping.

Waste Streams--

Environmental considerations include paper waste, printing and dyeing materials, and glue.

Folding Paperboard Boxes

This industry is marked by rather low concentration with the largest 50 firms accounting for 68 percent of the value of shipments. About 450 companies operate over 500 establishments that shipped products valued at $1.36 billion in 1972.

Manufacturing Processes--

Large rolls of paperboard are first printed by rotogravure, offset or letter press. Some water-base inks are used although they are not common. Printing may be followed by varnishing or coating to protect the surface. The paper is then cut, creased, and folded. The boxes are glued (usually waterbase) and shipped. Figure 12 describes the operation.

Waste Streams--

Environmental considerations include paper waste, printing materials, and glue.

Set-Up Paperboard Boxes

The set-up (rigid) paperboard box is characterized by low concentration with the 50 largest firms only accounting for 46 percent of industry shipments. In 1972, the value of shipments totaled $342.6 million.

Manufacturing Processes--

Rigid boxes are made from four materials: paperboard, corner stays, adhesive, and covering materials. First, flat sheets of cardboard are cut and scored to size. Individual blanks are separated from the sheet and the corners are cut out. Next, the sides of the blank are folded and the corners stayed. Staying may be accomplished with adhering paper, cloth, or metal reinforcements. The same process is repeated for the corner. Decorative coverings (wrappers) are adhered last. Figure 13 illustrates this process.

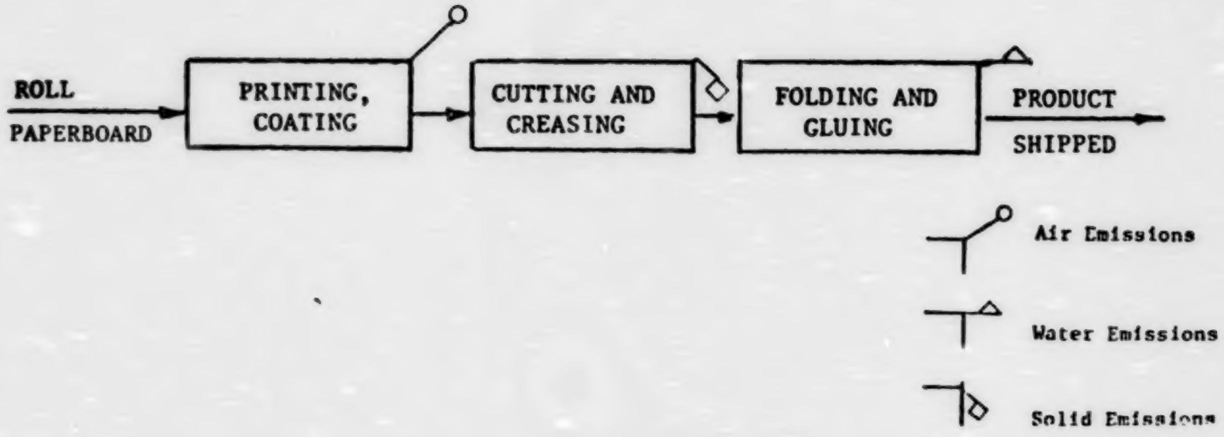
ROLL
PAPERBOARD
PRINTING, COATING
CUTTING AND CREASING
FOLDING AND GLUING
PRODUCT
SHIPPED
Air Emissions
Water Emissions
Solid Emissions

FIGURE 12. PRODUCTION OF FOLDING PAPERBOARD BOXES.

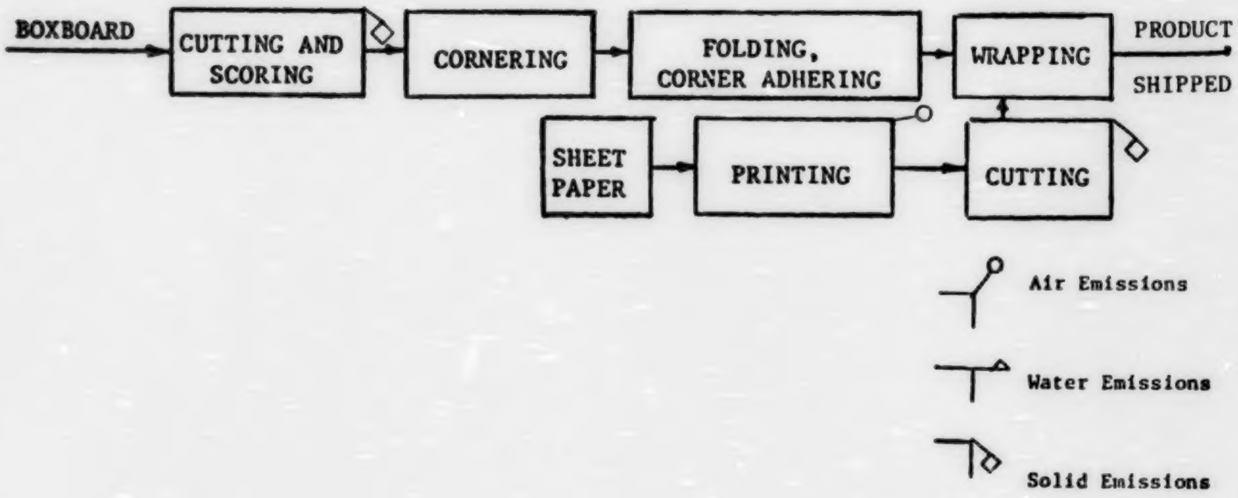
BOXBOARD
CUTTING AND SCORING
CORNERING
FOLDING, CORNER ADHERING
WRAPPING
PRODUCT SHIPPED
SHEET PAPER
PRINTING
CUTTING
Air Emissions
Water Emissions
Solid Emissions

FIGURE 13. PRODUCTION OF SET-UP PAPERBOARD BOXES.

Waste Streams--

Environmental considerations include paper waste and printing materials.

Corrugated and Solid Fiber Boxes

This group of converted paperboard products is the largest in the entire industry. In 1972, 709 companies operating 1,265 establishments produced products with a value of $4.2 billion. The industry is not highly concentrated.

Manufacturing Processes--

Unit processes are similar to those for folding boxes except for the base material (corrugated paper and fiber paper). In the corrugating machine, a fluted medium is made on a die and adhered to a Kraft liner at the "single facer" with an adhesive solution of cornstarch, caustic, and borax. This single-faced sheet is then processed through the double backer which applies the second facing, forming a single wall. This process may be repeated for thicker walls. Solid fiber boxes are made in a similar manner, but a different based adhesive (usually polyvinyl acetate) is used and there is no fluting. All types of printing are used in this industry. Figure 14 describes these processes.

Waste Streams--

Environmental considerations include wastepaper, glue and printing material.

Sanitary Food Containers

This industry is concentrated with four firms accounting for 41 percent of the shipments. The value of shipments totaled $1.4 billion in 1972. Traditionally, there has been much competition in certain portions of this industry between paper and plastic containers.

Manufacturing Processes--

To make paper cups and plates, roll paper is slit, moistened, printed (usually water-base), cut, and formed. Cups and other containers may require gluing. The cups may be either waxed or made from polyethylene-coated paperboard (which requires no seam gluing). Milk cartons and other containers are made in similar operations. Figure 15 describes these operations.

Waste Streams--

Environmental considerations are wastepaper, glue, and printing fluids.

Fiber Cans, Tubes, and Drums

The fiber cans, drums, and related materials had industry shipments of

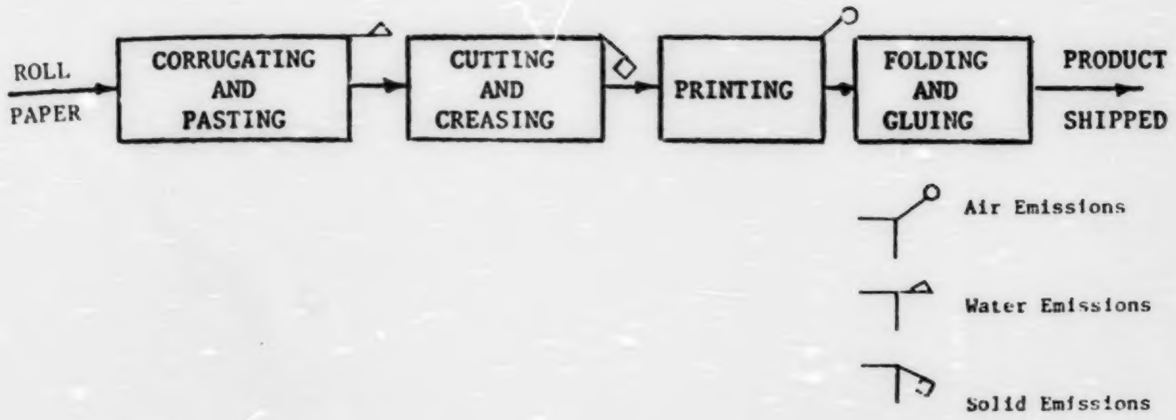
ROLL
PAPER
CORRUGATING AND PASTING
CUTTING AND CREASING
PRINTING
FOLDING AND GLUING
PRODUCT
SHIPPED
Air Emissions
Water Emissions
Solid Emissions

FIGURE 14. PRODUCTION OF CORRUGATED AND SOLID FIBER BOXES.

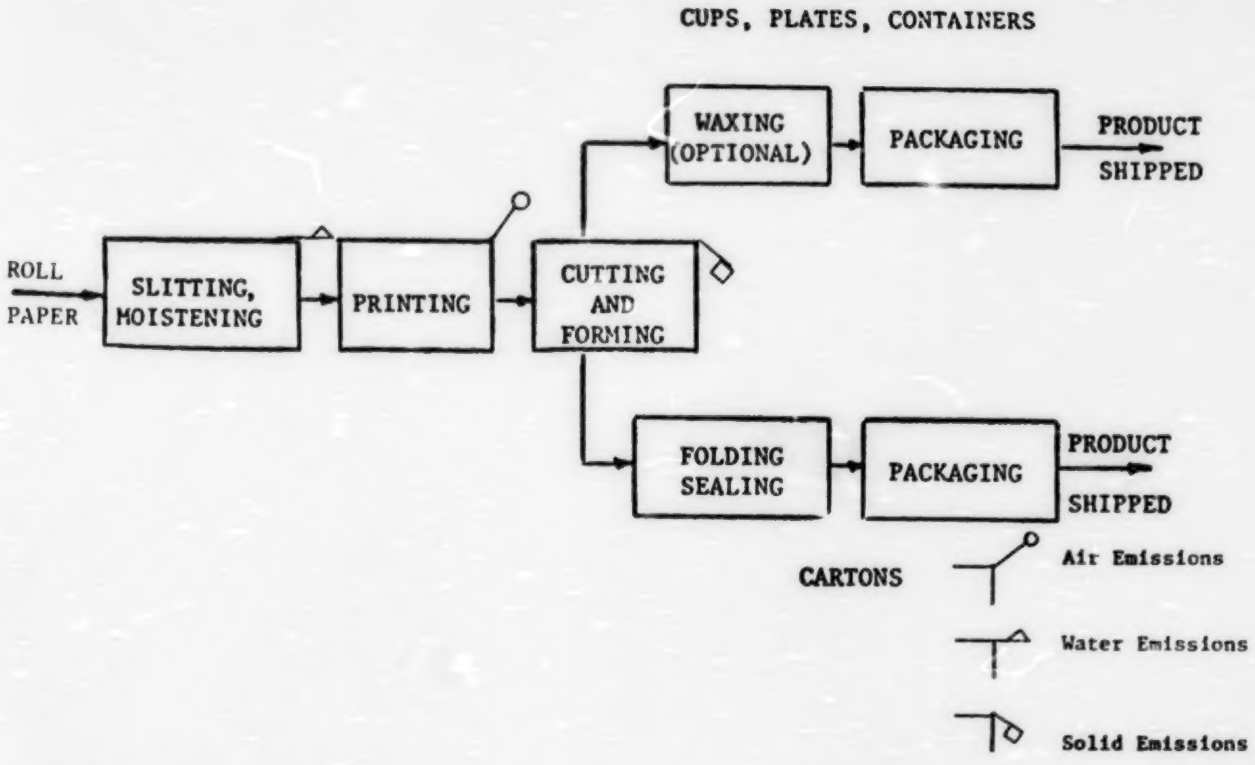
CUPS, PLATES, CONTAINERS
ROLL PAPER
SLITTING, MOISTENING
PRINTING
CUTTING AND FORMING
WAXING (OPTIONAL)
PACKAGING
PRODUCT SHIPPED
FOLDING SEALING
PACKAGING
PRODUCT SHIPPED
CARTONS
Air Emissions
Water Emissions
Solid Emissions

FIGURE 15. PRODUCTION OF SANITARY FOOD CONTAINERS.

$620 million in 1972. Over 160 companies operate plants, and the four largest producers account for 52 percent of the value of shipments.

Manufacturing Processes--

Large rolls of paper are first slit to the desired width and an adhesive is applied to one side as it is wound to the specified thickness and cut. The units can be left plain, painted, or silk screened to customer specifications. Cans and drums may be lined to accommodate the material they will be carrying.

Certain drums, etc., may require metal covers and/or parts at the ends. Many plants have their own metal finishing operations. Figure 16 describes these processes.

Waste Streams--

Environmental considerations include wastepaper, glue, and printing or painting materials. If metal finishing is included, this would involve cutting fluids, oils, degreasers, varnishes, varnish remover, deburring solutions. and special cleaners and surface preparation solutions.

PRINTING INDUSTRY

Printing and Publishing

There were 39,206 establishments in the United States primarily engaged in publishing and printing in 1972. An additional 2,889 establishments were engaged in direct services for the publishing and printing establishments.(1)

These 42,095 establishments employed 1,063,000 people, spent $10.045 billion for materials, and shipped products valued at $30.132 billion.

The printing of newspapers, periodicals, and books and commercial printing activities collectively accounted for about 81 percent of the establishments, employed 78 percent of the people, accounted for 80 percent of the value of materials purchased, and accounted for 80 percent of the value of shipments of the entire industry.

Newspapers--

Newspapers accounted for the greatest amount of printed matter produced in the United States. There were 8,116 establishments in 1972 primarily engaged in publishing and/or printing newspapers. They employed 349,000 people, spent $2.045 billion for material, and shipped products valued at $8.27 billion. Some of these establishments engaged in commercial printing, but some others have part or all of their printing done by commercial printers.

Periodicals--

There were 2,535 establishments primarily engaged in publishing and/or printing periodicals in 1972. They employed 67,000 people, spent $1.41

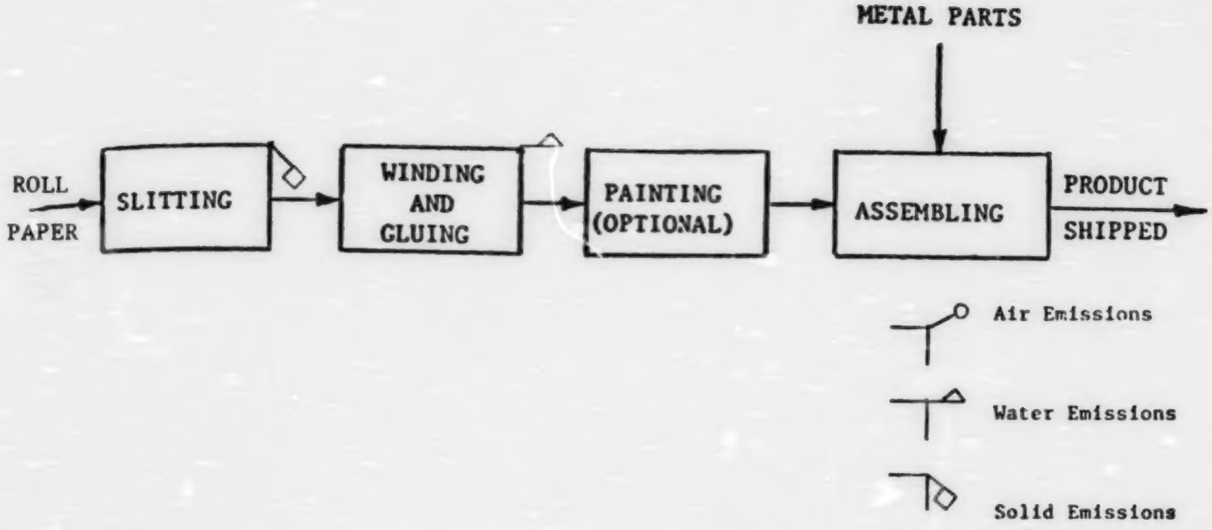
METAL PARTS
ROLL PAPER
SLITTING
WINDING AND GLUING
PAINTING (OPTIONAL)
ASSEMBLING
PRODUCT SHIPPED
Air Emissions
Water Emissions
Solid Emissions

FIGURE 16. FIBER CANS, TUBES, DRUMS AND SIMILAR PRODUCTS.

billion for materials, and shipped products valued at $3.521 billion. Their publications include magazines, trade journals, comic books, and statistical reports.

Books--

There were 1,905 establishments in 1972 primarily engaged in publishing and/or printing and binding books and pamphlets. These establishments employed 98,000 people, spent $1.292 billion for supplies, and shipped products valued at $3.794 billion.

Commercial Printing--

There were 21,584 establishments in 1972 primarily engaged in commercial printing by letterpress and/or lithographic processes. These establishments employed 314,000 people, spent $3.293 billion for materials, and shipped products valued at $8.414 billion. The average employment by these establishments is about 15 people, indicating many small establishments. In fact, 12,108 such establishments employ fewer than 5 people, whereas only 40 employ 500 or more people.

In addition to labels, wrappers, catalogs, directories, advertising, financial, legal, and general job printing, some shops specialize in printing newspapers and periodicals for others. These letterpress and lithographic printers purchased 13 percent as much newsprint as did the newspaper publishers and printers.

Manufacturing Processes--

Figure 17 shows a general flow sheet for the printing of newspapers, periodicals, books, and the products of commercial lithographic and letterpress printing. Most of these printing processes, regardless of the products, share many of the same unit operations. The major difference between lithographic and letterpress printing is the preparation of a plate from a photographic medium in the former and the use of some form of typesetting in the latter. Letterpress printing is gradually being replaced by lithographic and other photo-dependent processes. The nature of the printed product dictates the manner in which it is finished, as shown in Figure 17. In the following paragraphs, unit operation will be discussed.

Photography--Particularly for lithographic offset printing, the prepared copy is first photographed. This photographed material is subsequently transferred to a printing plate.

Other than the prepared copy, the major materials used are photographic film and processing chemicals. The processing chemicals are complex mixtures of organic and inorganic chemicals designed to perform developing, fixing, and reducing functions to bring out the latent image in the photographic emulsion.

Preparation of Printing Plate--A lithographic or a photo-offset plate is prepared from the photographic image. Lithographic plates, generally

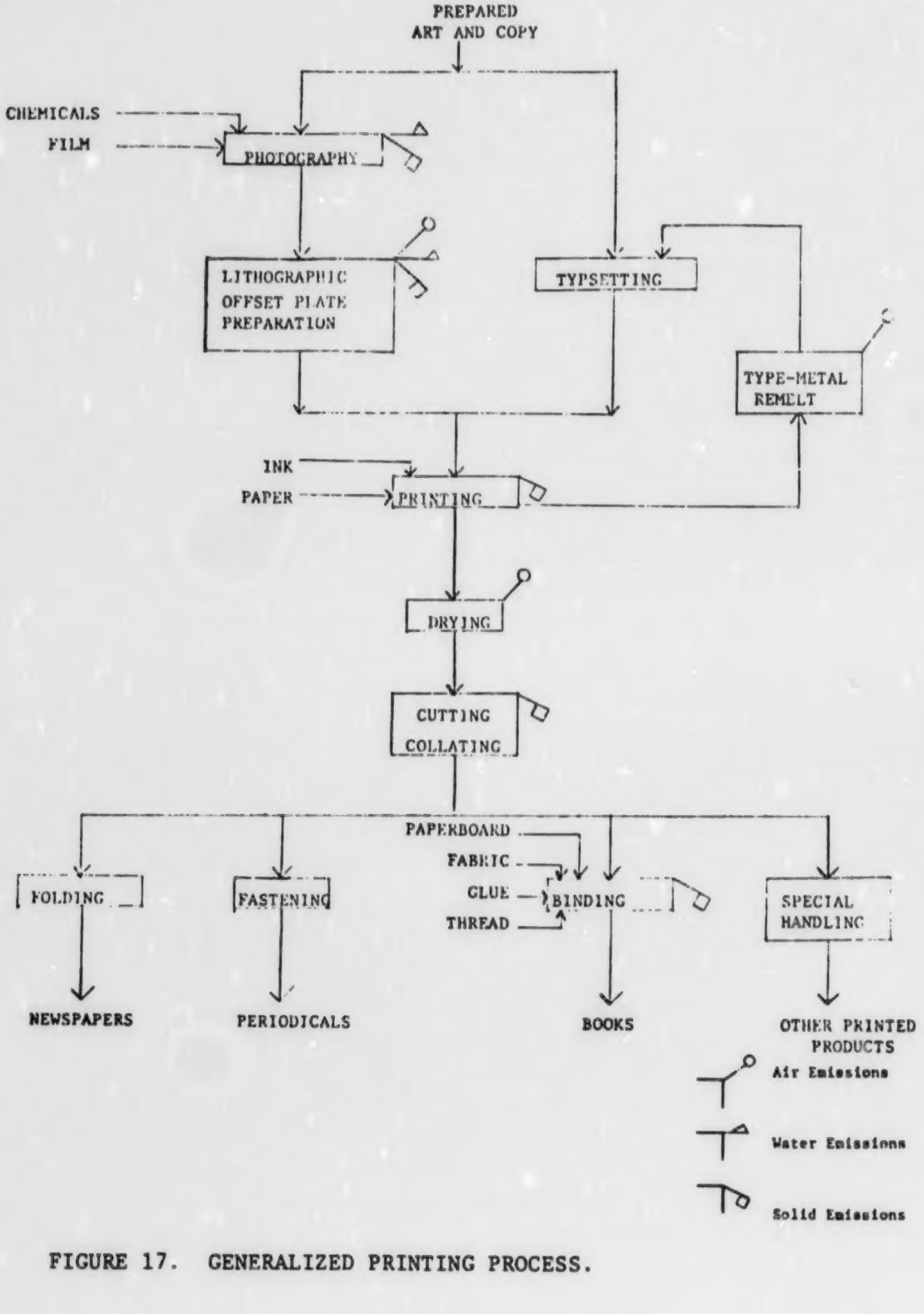
PREPARED ART AND COPY
CHEMICALS
FILM
PHOTOGRAPHY
LITHOGRAPHIC OFFSET PLATE PREPARATION
TYPSETTING
TYPE-METAL REMELT
INK
PAPER
PRINTING
DRYING
CUTTING COLLATING
PAPERBOARD
FABRIC
GLUE
THREAD
FOLDING
FASTENING
BINDING
SPECIAL HANDLING
NEWSPAPERS
PERIODICALS
BOOKS
OTHER PRINTED PRODUCTS
Air Emissions
Water Emissions
Solid Emissions

FIGURE 17. GENERALIZED PRINTING PROCESS.

aluminum, are covered with a polymeric coating. Illumination through the developed photographic transparency causes crosslinking and hardening of the coating in some systems, or may cause depolymerization and softening in others. The non-hardened portions are subsequently dissolved off, leaving hydrophobic areas as ink receptors for printing.

Lithographic plates are generally made of aluminum and are not reused. However, there is some usage of reusable zinc plates. Disposable plastic plates are coming into common usage, and bimetallic plates (copper or steel) may be used for long runs.

Coating materials may be diazo resins or various other synthetic polymers.

Chemicals used in processing the plates include various inorganic and organic acids and a variety of organic solvents.

Printing--For the printing operation, the printing plate or preset type is affixed to the printing press. As the press moves, the printing plate or type face picks up ink and transfers it to the paper. The major input materials are the carrier of the printing image (plate or type), paper, and printing ink.

Type-Metal Remelt--In linotype printing, which is tending to become obsolete, a line of type characters is cast on demand from a keyboard as a solid metal slug. After use, the metal is remelted for reuse.

Drying--After printing, the paper on which the wet ink has been placed is run rapidly through an oven to dry the ink. Depending on the type of ink used, the drying process may involve crosslinking of a liquid polymer and/or vaporization of a solvent. Some solvent-free, UV-curable ink resins are coming into use.

Cutting and Collating--The printed roll paper is cut into sheets of the appropriate size, which are arranged in proper numerical sequence.

Binding--Books are bound in either hard-cover or paperback form. Other types of publications are generally bound in a simpler manner. Most periodicals, for example, are stapled together and newspapers are merely folded together.

Materials used in binding include thread for sewing book sections together, paperboard, glue, and preprinted fabric or special paper. A thin plastic sheet may be laminated to the outside of paperback books.

Waste Streams--

In the following paragraphs, those unit operations that generate waste products will be discussed.

Photography--The major waste stream from this unit operation is the wastewater stream containing used processing chemicals. Some of these chemicals have been oxidized or reduced in part to forms different from those in which they entered the system. In addition, unexposed silver halide has been removed from the emulsion and is contained in the wastewater as silver ferrocyanide, a soluble salt. Some of the larger establishments can profitably recover the silver values from this stream.

There is also some potential for solid waste in the photographic section. Once the copy has been reduced to a photographic image, the original has no further use to the printer. Furthermore, the containers in which both film and chemicals are received must be disposed of. It is assumed that, in most cases, there will be little need for the production and ultimate disposal of duplicate photographic images.

Preparation of Printing Plate--The waste products from processing the printing plates are liquid in nature and would be contaminants of wastewater. Some of the solvents used are volatile and are modest air contaminants.

The photographic material must be disposed of after the plate is made and makes a contribution to solid waste.

Printing--The major waste from the printing operation is the non-reusable plate that must be disposed of as a solid waste.

Type-Metal Remelt--There should be no waste stream other than gaseous effluents from the fuel used to supply heat.

Drying--Any solvent that is vaporized in the oven would constitute a gaseous effluent to the air. High volume web printing systems can emit significant quantities of air contaminants, and in some processes, vaporized resins and smoke. Air pollutants from drying ovens are odorous, and can be irritating to the eyes. When irradiated by sunlight in the presence of oxides of nitrogen, even more noxious pollutants are formed.

Cutting and Collating--The only waste stream from this operation is edge trimmings and perhaps an occasional spoiled sheet, providing a modest amount of paper as a solid waste.

Binding--Only solid wastes arise from book binding. These wastes comprise trimmings from the input materials and perhaps an occasional spoiled cover or book.

COMPOUNDED ORGANIC CHEMICAL PRODUCTS

Many types of chemical products are formulated or fabricated for use by consumers or by other industries. Examples of such products include pharmaceutical preparations, soaps and other detergents, cleaners, polishes, sanitary preparations, textile agents, perfumes, cosmetics, paints, adhesives and sealants, and printing inks.

In 1972 there were 7,405 establishments primarily engaged in producing such products. They employed 351,400 people, purchased materials valued at \$9.142 billion, and shipped products valued at \$24.4 billion.(1)

Five segments of this very diverse industry accounted for 64 percent of the total establishments in the industry, 49 percent of employment, purchased 77 percent of the dollar value of materials, and shipped 83 percent of the dollar value of products. Table 1 shows pertinent information on these five industry segments. Manufacturing processes will be discussed for these and some of the smaller segments of the industry.

Pharmaceutical Preparations

Other segments of the pharmaceutical industry are primarily engaged in manufacturing biological products, medicinals, and botanical products in bulk. The major activity of this segment of the industry is fabricating or processing drugs into pharmaceutical preparations for human or veterinary use. Most of the ingredients used are purchased in bulk from other suppliers, although many of the larger companies manufacture some of the ingredients they use.

Pharmaceutical preparations are classified as ethical or proprietary Ethical pharmaceuticals are promoted to physicians, dentists, or veterinarians for their direct use or to be prescribed for the public. Proprietary pharmaceuticals are promoted directly to the public for over-the-counter sales for use on humans or animals. Proprietary pharmaceuticals account for about 75 percent of the total value of shipments of all pharmaceutical preparations for human and veterinary use. Veterinary pharmaceuticals (both ethical and proprietary) account for only about 3.5 percent of the value of shipments of all pharmaceutical preparations.

About half (379) of the 756 establishments shown in Table 1 employed fewer than 10 people in 1972, whereas 24 establishments employed 1000 people or more. Average employment was 148 people per establishment.

Manufacturing Processes--

Pharmaceutical preparations may be used in solid, semi-solid, liquid, or gaseous forms. A wide variety of dosage forms exists, including tablets, hard and soft gelatin capsules, powders, microcapsules, ointments, creams, suspensions, solutions, syrups, lozenges, aerosols, inhalants, injectibles, and others. All establishments engaged in formulating pharmaceutical preparations must be equipped to produce one or more of these dosage forms.

Most of the equipment and the general processes used in formulating pharmaceutical preparations are common to many other products. However, some aspects of the processing are unusual. Most products are prepared in relatively small batches, and different products are processed in the same equipment. This leads to an unusual amount of cleaning of equipment prior to changing from one product to another. Many of the process operations are conducted in separate rooms to prevent any cross contamination of products. Quality control is more important in the formulation of pharmaceutical

TABLE 1. MAJOR INDUSTRY SEGMENTS THAT PRODUCE COMPOUNDED ORGANIC CHEMICAL PRODUCTS

Industry Segment	Establishments	Employees, 1000	$ Million	
			Cost of Materials	Value of Shipments
Pharmaceutical preparations	756	112.0	1,576	7,150
Soap and detergents	642	31.5	1,374	3,394
Cleaning, polishing, and sanitary preparations	1,108	25.1	759	1,868
Perfume, cosmetics, and toilet preparations	646	48.3	1,243	4,057
Paint, varnish, etc.	1,599	66.0	2,061	3,824

preparations than it is in most other industries. Finally, inventory control is very important at all stages of production, packaging, labeling, storage, and shipment.

Very general diagrams are shown for production of the more common dosage forms of pharmaceutical preparations. Figure 18 is a generalized process for fabricating tablets or capsules. Tablets may be made by a wet or dry process, depending on stability and other properties of the ingredients.

Figure 19 shows a general process for producing liquid pharmaceutical preparations. Except for the need for sterile conditions and quality control, this is a very simple process.

Figure 20 shows a general process for producing semi-solid pharmaceutical preparations, such as ointments, creams, and suppositories. The relative difficulty of working the ingredients together determines the type of milling or emulsification required.

Figure 21 shows a general process for producing parenteral solutions for injection. Since these solutions enter directly into the body without first going into the intestinal tract, aseptic conditions are particularly important.

Waste Streams--

The most significant waste streams are probably the aqueous wastes generated in cleaning equipment. These wastes contain many types of biological agents.

Dusting occurs in many of the process steps. Since both air temperature and humidity must be controlled, and dust must be kept away from both workers and other products, an elaborate air-filtration system is required or a great deal of outside air must be conditioned. The dust is ultimately an air contaminant, water contaminant, or solid waste.

When non-aqueous solvents are used, small amounts may be air contaminants or water contaminants from the cleaning operations.

Shipping containers in which ingredients or preformed packaging units are received make a contribution to solid waste. Breakage may also make a contribution to solid waste.

Soap and Detergents

This segment includes establishments primarily engaged in the manufacturing of soap, synthetic organic detergents, inorganic alkaline detergents, or any combination thereof, and establishments producing crude and refined glycerin from vegetable and animal fats and oils.

Three large companies (out of over 300) dominate the household detergent market with over 80 percent of the business. They have a lesser position in laundry detergents, other household cleaning products, and industrial cleaning

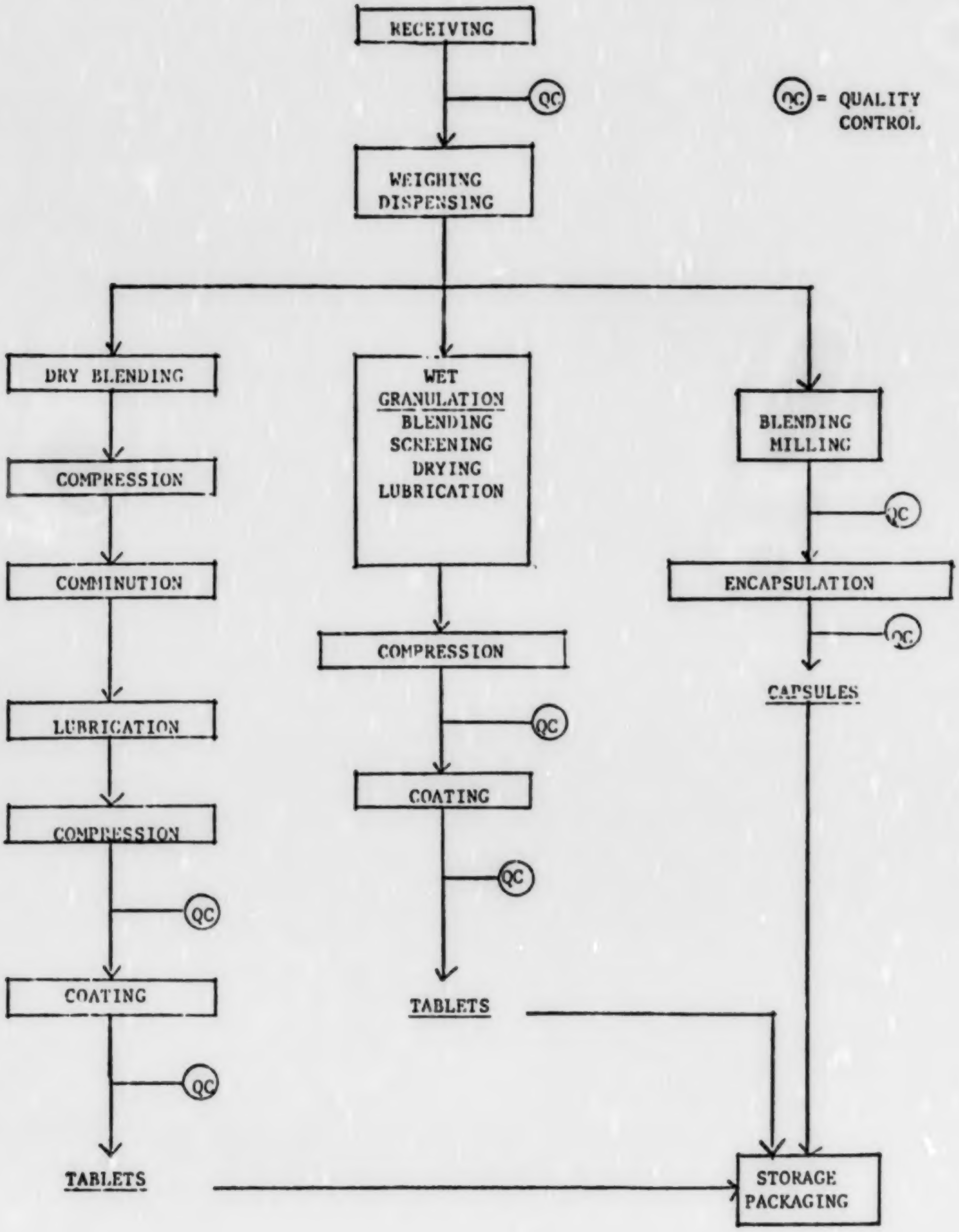
RECEIVING
QC
QC = QUALITY CONTROL
WEIGHING DISPENSING
DRY BLENDING
WET GRANULATION
BLENDING
SCREENING
DRYING
LUBRICATION
BLENDING MILLING
COMPRESSION
COMMINUTION
QC
ENCAPSULATION
QC
COMPRESSION
CAPSULES
LUBRICATION
QC
COATING
COMPRESSION
QC
QC
COATING
QC
TABLETS
TABLETS
STORAGE PACKAGING

FIGURE 18. PRODUCTION OF PHARMACEUTICAL TABLETS AND CAPSULES. Source: Versar Report.(5)

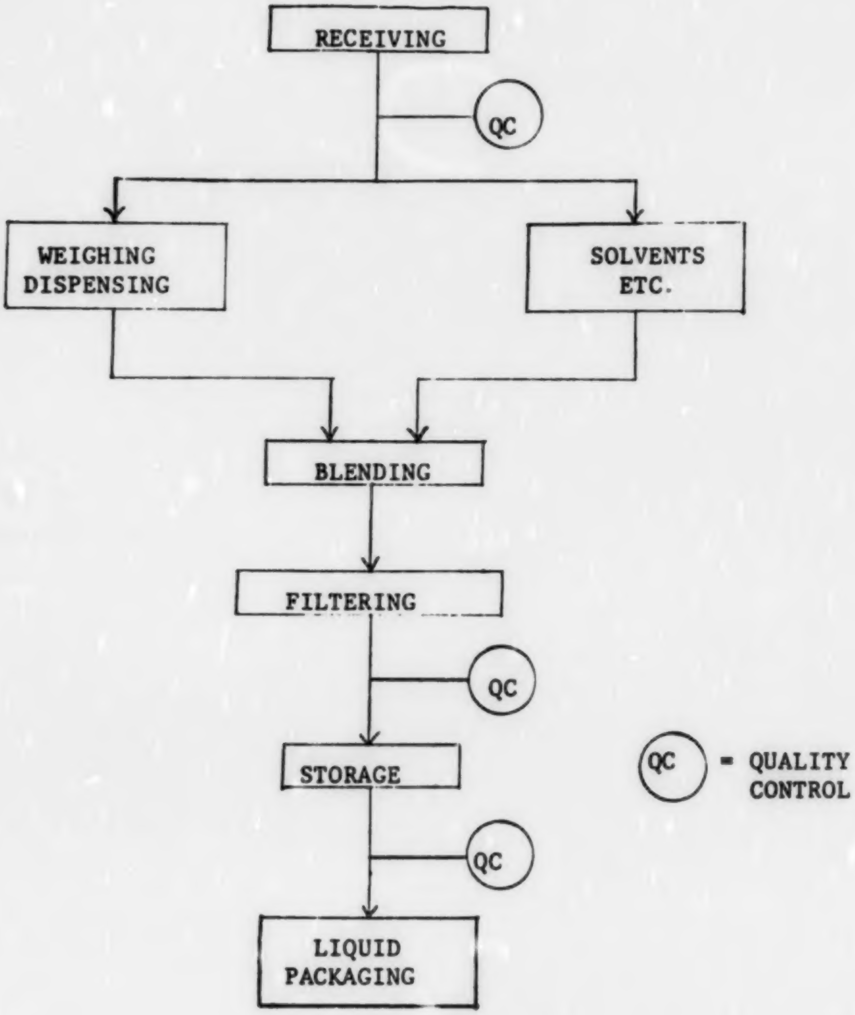
RECEIVING
QC
WEIGHING DISPENSING
SOLVENTS ETC.
BLENDING
FILTERING
QC
STORAGE
QC
LIQUID PACKAGING
QC = QUALITY CONTROL

FIGURE 19. PRODUCTION OF LIQUID PHARMACEUTICAL PREPARATIONS.
Source: Versar Report (5).

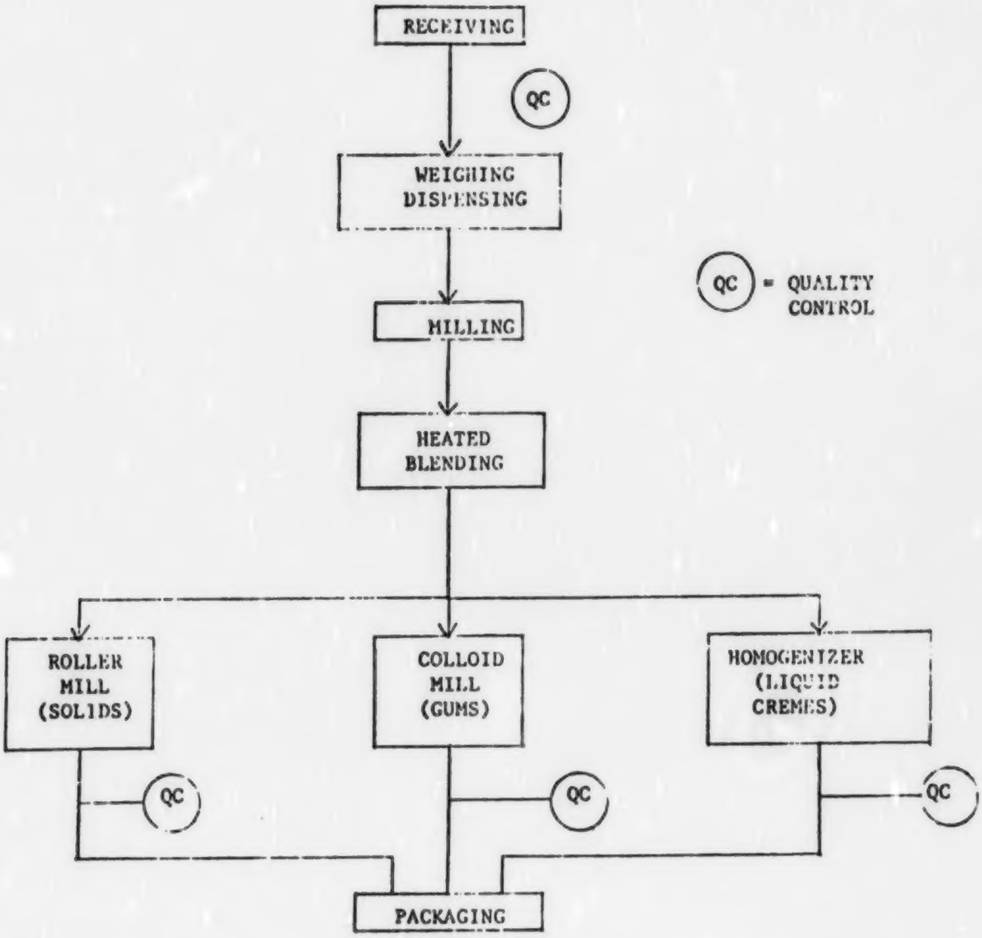
RECEIVING
QC
WEIGHING
DISPENSING
QC = QUALITY CONTROL
MILLING
HEATED
BLENDING
ROLLER
MILL
(SOLIDS)
COLLOID
MILL
(GUMS)
HOMOGENIZER
(LIQUID
CREMES)
QC
QC
QC
PACKAGING

FIGURE 20. PRODUCTION OF SEMI-SOLID PHARMACEUTICAL PREPARATIONS.
Source: Versar Report.(5)

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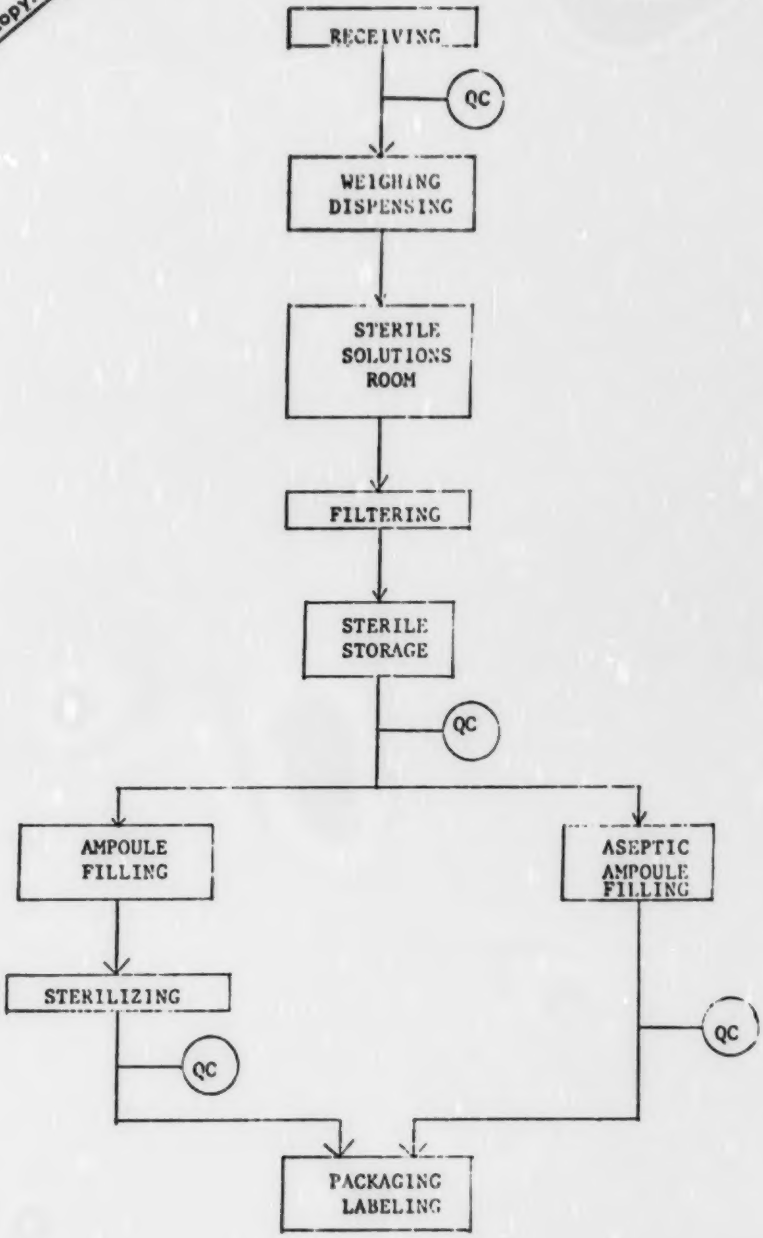

RECEIVING
QC
WEIGHING DISPENSING
STERILE SOLUTIONS ROOM
FILTERING
STERILE STORAGE
QC
AMPOULE FILLING
ASEPTIC AMPOULE FILLING
STERILIZING
QC
QC
PACKAGING LABELING

FIGURE 21. PRODUCTION OF PARENTERAL PHARMACEUTICAL PREPARATIONS.
Source: Versar report(5)

compounds. Overall in 1972, fifteen establishments (out of 642) accounted for 47 percent of the value of shipments.

Manufacturing Processes--

Basic raw materials are caustics, fats, oils, salts, and surfactants. The soap-making processes, either those utilizing the alkaline saponification of fats and oils or those employing the saponification of fatty acids, may be either batch or continuous. The steps or operations performed include saponification of the fats and oils by boiling in a caustic solution using live steam, followed by "graining" or precipitating the soft curds of soap out of the aqueous lye solution by adding sodium chloride. The soap solution then is washed to remove glycerine and color body impurities to leave the settled or neat soap to form on standing.

A typical product of this industry is bar soap. Most bar soap today is manufactured by the "milling" process. Milled soaps, as they are called by the industry, usually are manufactured by one of two processes. In the older and still more commonly used process shown in Figure 22, the soap stock is batched in a mixer, called a "crutcher", with other ingredients. The batch is then flowed onto chill rolls, and then flaked off and passed through a steam-heated hot-air dryer. The flakes can be packaged as flake soap or ground and packaged as powder. When soap bars are made, the flakes from the dryer are "plodded" (mixed in a screw or sugar tubular mixer) or mixed with final ingredients such as perfume. The plodded material then is fed to a roll mill. The flaky soap produced by the roll mill then is plodded again to throughly mix ingredients and improve texture and is extruded in a continuous bar shape for cutting, stamping, and wrapping.(2)

Waste Streams--

All chemical processes and some of the other operations involved in making soap, production of fatty acids, and the purification of glycerine have odors as a common air pollution problem. Blending, mixing, drying, packaging, and other physical operations are subject to the air-pollution problems of dust emissions. Process water is used to clean up the various pieces of equipment, therefore the wastewater will be mainly soap. Most of the soap wastes would be recycled. Solid waste results from the packaging operations.

Polishes, Bleaches and Sanitation Products

This segment includes establishments primarily engaged in manufacturing furniture, metal and other polishes; waxes and dressings for fabricated leather and other materials; household, institutional, and industrial plant disinfectants and deodorants; household bleaches; dry cleaning preparations; and other sanitary preparations. This segment is composed of 1108 establishments operated by 1023 companies.

Manufacturing Processes--

Most of the products of this industry segment are prepared as solutions, emulsions, or pastes, although some are prepared in solid form. Blending and

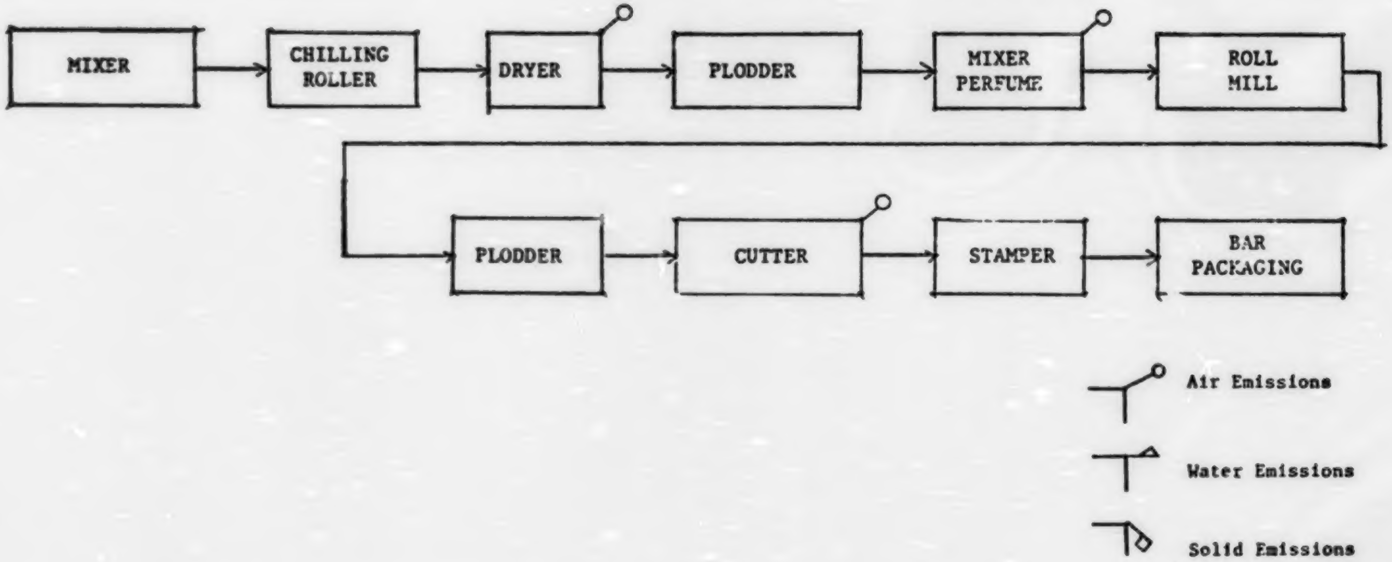

MIXER
CHILLING ROLLER
DRYER
PLODDER
MIXER PERFUME
ROLL MILL
PLODDER
CUTTER
STAMPER
BAR PACKAGING
Air Emissions
Water Emissions
Solid Emissions

FIGURE 22. FLOW DIAGRAM MILLING SOAP BARS.(2)

mixing are common operations in this industry. No specific process representative of this industry segment was found. The simplified diagram shown in Figure 23 should be fairly typical of processes used in preparing emulsions or pastes.

Waste Streams--

Odors may be evolved in all of the process steps. Some particulate matter may also be evolved in the milling operations. Water pollution should not arise from the actual process operations, although cleanup of spills and cleaning of equipment would contribute to water pollution. Solid wastes would include the containers in which starting materials were received.

Toilet Preparations

This segment of the industry includes establishments primarily engaged in manufacturing perfumes, cosmetics, and other toilet preparations. This segment also includes establishments primarily engaged in blending and compounding perfume bases, and those manufacturing shampoos and shaving products. This segment is composed of 646 establishments operated by 594 companies.

Manufacturing Processes--

One of the leading products in this segment is shampoo. The manufacture of shampoos is relatively simple. Generally, the only major equipment needed are stainless steel manufacturing kettles jacketed for heating and cooling, and equipped with adequate agitation. Shampoos normally consist of water solutions or suspensions of one or more cleansing agents combined with other ingredients or additives.(6)

Synthetic detergents are generally used as cleansing ingredients, although soap also finds some application. Additives include thickeners, opacifiers, conditioners, lime-soap dispersants, sequestrants, solubilizing and coupling agents, bacteriostatic and fungistactic materials, perfume, color, etc.

Waste Streams--

Water is used for cleaning the process kettles. The wastewater includes diluted shampoo. Alcohol and solvents are also used to clean the process kettles. Air pollution could consist of various odors.

Paint and Allied Products

This industry is composed of establishments primarily engaged in the manufacturing of paints (in paste and ready-mixed form), varnishes, lacquers enamels, and shellac; putties, wood fillers, and sealers; paint and varnish removers; paint brush cleaners; and allied paint products.

The paint and varnish industry is one of the oldest manufacturing industries in the United States. The industry is made up of about 1,500 companies currently operating about 1,700 plants.(7) The industry is well

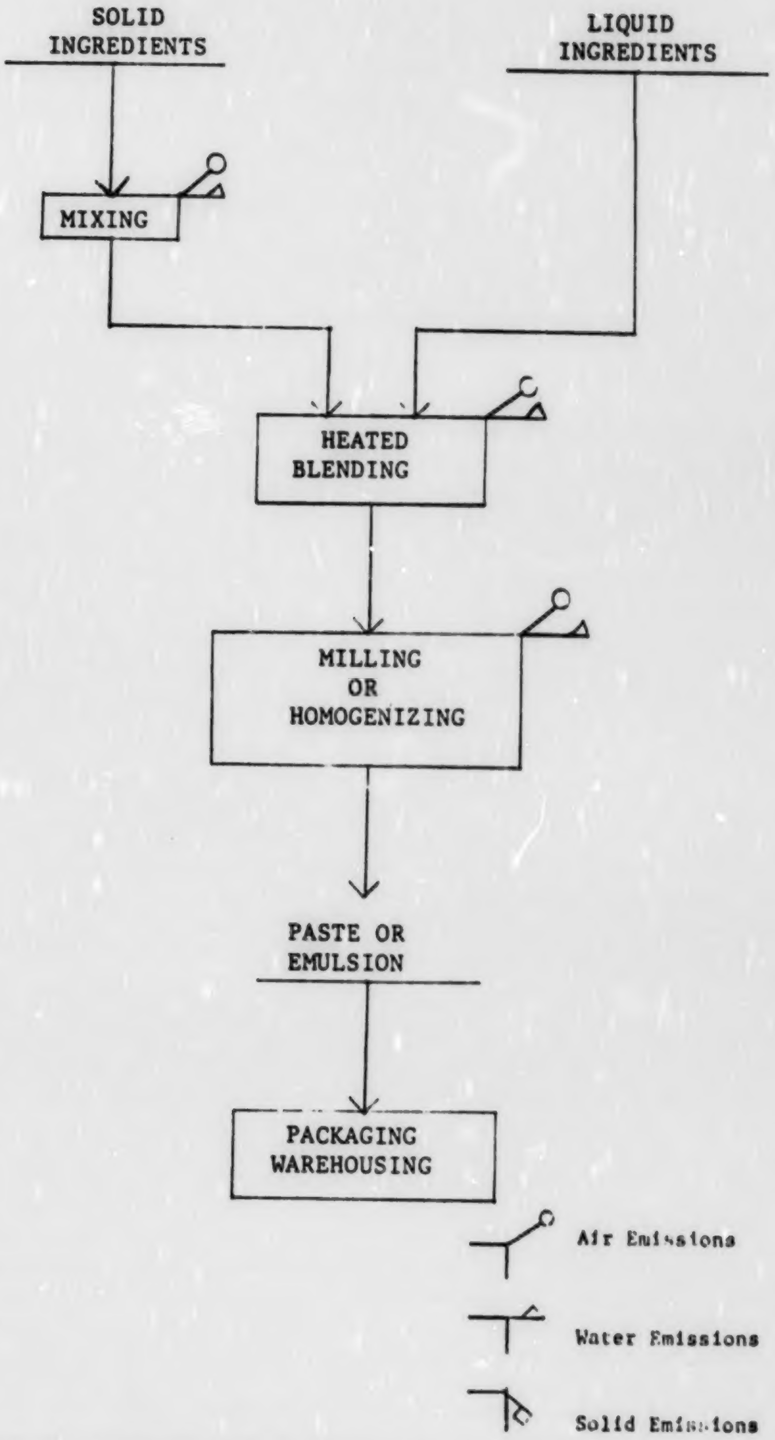

SOLID INGREDIENTS
LIQUID INGREDIENTS
MIXING
HEATED BLENDING
MILLING OR HOMOGENIZING
PASTE OR EMULSION
PACKAGING WAREHOUSING
Air Emissions
Water Emissions
Solid Emissions

FIGURE 23. PRODUCTION OF PASTES OR EMULSIONS.

distributed geographically throughout the country and production volume is definitely related to density of population. Even though about 36 companies account for about 64 percent of the total sales, the industry is one of the few remaining which contains numerous small companies that specialize in a limited product line to be marketed within a geographic region. There are fewer than 20 companies that sell paint nationwide.

Manufacturing Processes--

Paints can be divided into two categories, (1) water-base paint and (2) oil-base paint. The major production difference is in the carrying agent--oil-base paints are dispersed in an oil mixture, while water-base paints are dispersed in water with a biodegradable surfactant used as the dispersing agent. The next significant difference is in the cleanup procedures. As the water-base paints contain surfactants, it is much easier to clean up the tubs with water. The tubs used to make oil-base paint are generally cleaned with an organic solvent, but cleaning with a strong caustic solution is also a common practice.(8,9)

There are three major steps in the manufacturing of oil-base paints: (1) mixing and grinding of raw materials, (2) tinting and thinning, and (3) filling operations. The flow diagram in Figure 24 illustrates these steps.

At most plants, the mixing and grinding of raw materials for oil-base paints are accomplished in one production step. For high-gloss paints, the pigments and a portion of the binder and vehicle are mixed into a paste of a specified consistency. This paste is fed to a grinder, which disperses the pigments by breaking down particle aggregates rather than by reducing the particle size. Two types of grinders are ordinarily used for this purpose: pebble or steel ball mills, or roll-type mills. Other paints are mixed and dispersed in a mixer using a sawtoothed dispersing blade.

In the next stage of production, the paint is transferred to tinting and thinning tanks, occasionally by means of portable transfer tanks but more commonly by gravity feed or pumping. Here, the remaining binder and liquid, as well as various additives and tinting colors, are incorporated. The paint is then analyzed and the composition is adjusted as necessary to obtain the correct formulation for the type of paint being produced. The finished product is then transferred to a filling operation where it is filtered, packaged and labeled.(8,9) In a large plant, these operations are usually mechanized.

Water-base paints are produced by a slightly different method than oil-base paints. Figure 25 illustrates a typical process for manufacturing water-base paints. The pigments and extending agents are usually received in proper size, and the dispersion of the pigment, surfactant, and binder into the vehicle is accomplished with a saw-toothed disperser. In small plants, the paint is thinned and tinted in the same tub, while in the larger plants the paint is transferred to special tanks for final thinning and tinting. Once the formulation is correct the paint is transferred to a filling operation where it is filtered, packaged, and labeled in the same manner as for oil-base paints.

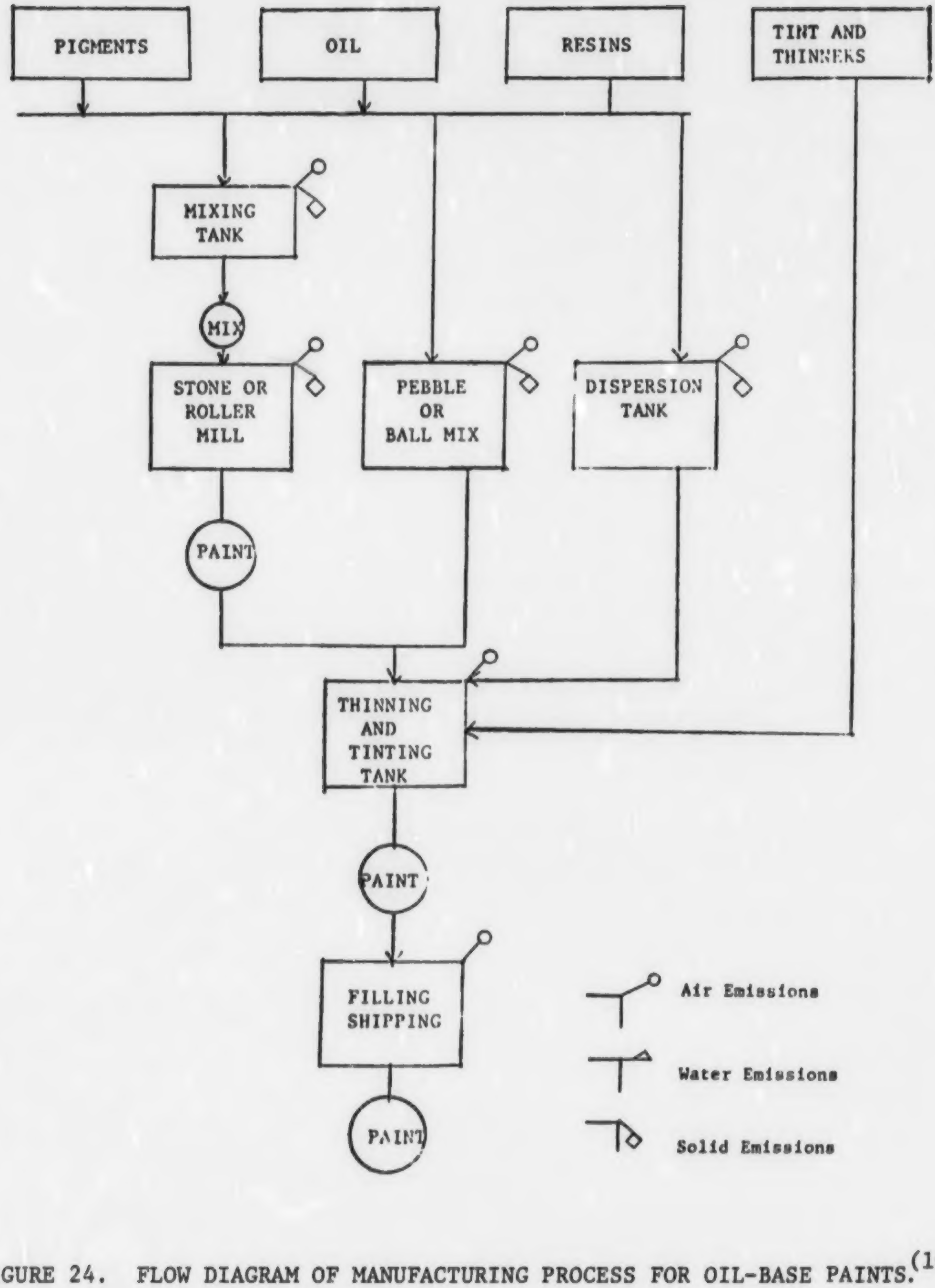

PIGMENTS
OIL
RESINS
TINT AND THINNERS
MIXING TANK
MIX
STONE OR ROLLER MILL
PEBBLE OR BALL MIX
DISPERSION TANK
PAINT
THINNING AND TINTING TANK
PAINT
FILLING SHIPPING
PAINT
Air Emissions
Water Emissions
Solid Emissions

FIGURE 24. FLOW DIAGRAM OF MANUFACTURING PROCESS FOR OIL-BASE PAINTS.(10)

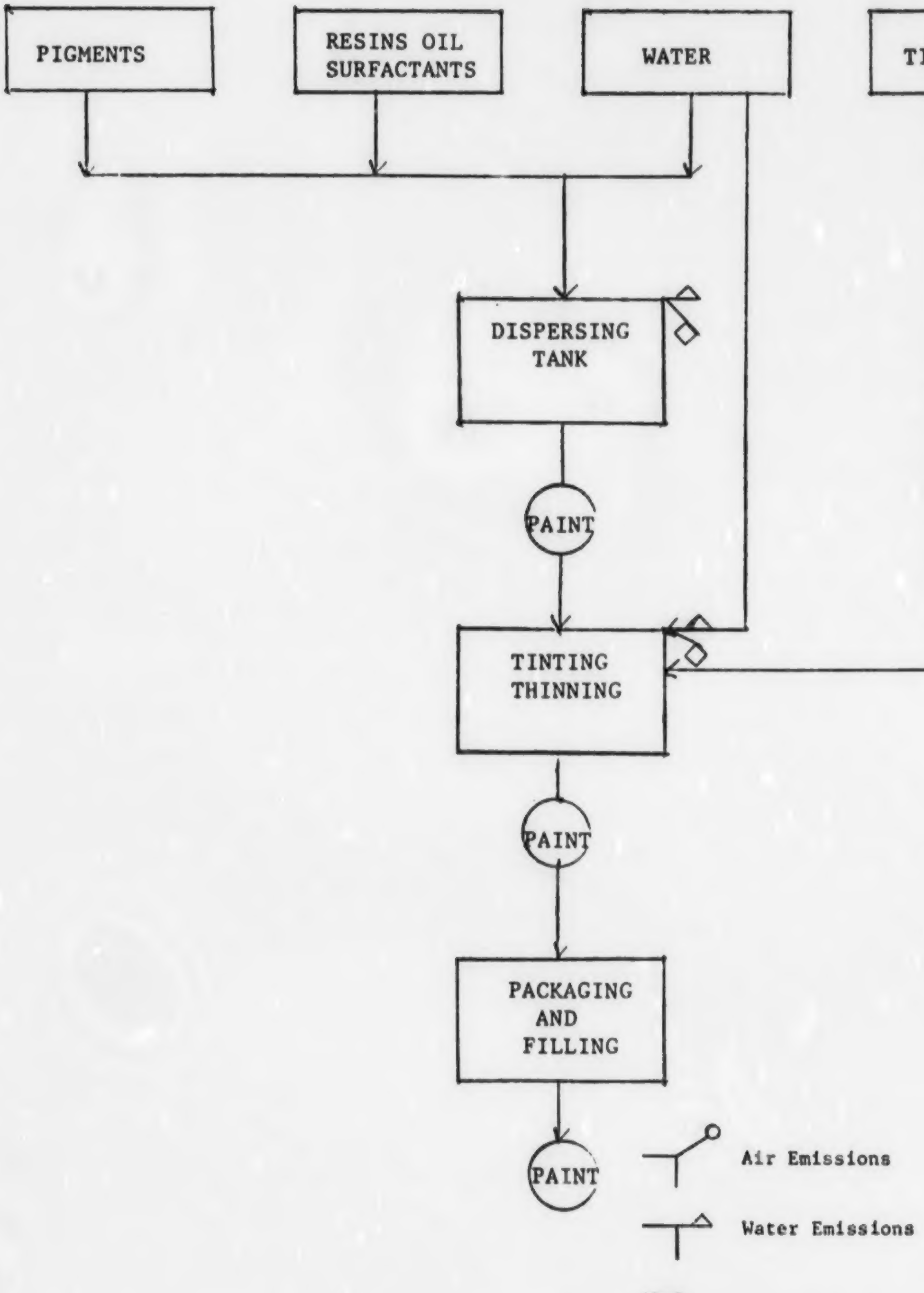

PIGMENTS
RESINS OIL SURFACTANTS
WATER
TINTS
DISPERSING TANK
PAINT
TINTING THINNING
PAINT
PACKAGING AND FILLING
PAINT
Air Emissions
Water Emissions
Solid Emissions

FIGURE 25. FLOW DIAGRAM OF MANUFACTURING PROCESS FOR WATER-BASE PAINTS.(10)

Waste Streams--

Air emissions result from the grinding and mixing operations of dry materials and the addition of solvents to the tinting and thinning operations. Solid waste in the form of sludge is a result of the cleanup operation. Wastewater is generated from the tubwashing operations in the manufacture of water-base paints. The final cleanup for oil-base paint tubs consists of flushing with a petroleum solvent until clean. The dirty solvent is then treated one of three ways: (1) it is used in the next paint batch, (2) it is sold to a solvent reclaiming company where it is sometimes redistilled and resold, or (3) it is placed in a drum and the cleaner solvent decanted for subsequent tank cleaning and return to drums until only sludge remains in the drum. The drum of sludge is then sent to a landfill for disposal.

Manufacturing Processes--

Varnish cooking processes are conducted in two types of vessels--the open-topped portable kettle and the newer, totally enclosed, stationary kettle.

The open kettles are cylindrical vessels with dished or flat bottoms. They usually are transported on a three- or four-wheel truck, and are heated over an open flame. This type of kettle usually varies in capacity from 185 to 375 gallons and is made of steel, copper, monel, aluminum, nickel, or stainless steel. Under most operating conditions, the kettle is charged in a loading room and then moved to the fire pit. It is heated over the fire pit; then, when the reaction is complete, transferred to another location for cooling. The thinning process involves pumping the hot varnish to another vessel which contains cold solvent, and some solvent to volatilize to the atmosphere during this operation. In the past, it was common to manually agitate the contents during cooking. Materials in open kettles now are seldom agitated manually. Agitation is provided by air-driven or electrically driven mixers and by sparging the contents with an inert gas, such as carbon dioxide or nitrogen. The open kettle still is employed extensively in varnish-manufacturing establishments.(2)

The closed stationary vessels are almost exclusively found at chemical companies engaged in manufacturing of a wide variety of paint bases.

Waste Streams--

Vapor or gases are emitted from the open kettles during the cooking process. Water pollution results when wet scrubbers are used to control air emissions, and when the cooking tubs are cleaned, using a caustic cleaning solution. The caustic cleaning solution is reused and diluted or treated before discharging to the municipal sewer system. Solid wastes are treated and shipped to landfills.

Adhesives and Sealants

This industry is made up of establishments primarily engaged in manufacturing industrial and household adhesives, glues, caulking compounds, sealants, and linoleum, tile, and rubber cements. It can be further categorized by product type as follows:

1. Natural base glues and adhesives
2. Synthetic resin and rubber adhesives, and
3. Caulking compounds and sealants.

Essentially, this is a compounding or formulating industry. In general, raw materials are manufactured under other industrial classifications although some companies may manufacture chemical raw materials for adhesives and sealants and also manufacture the finished products. The 1974-1975 adhesives Red Book lists 745 companies and 1114 plants engaged in the manufacture of adhesives, ranging in size from less than 5 to over 1,000 employees. On the other hand, the 1972 Census of Manufactures lists only 463 establishments as being primarily engaged in manufacturing adhesives and sealants. They employed 14,900 people, purchased materials valued at $504 million, and shipped products valued at $928 million.(1) The synthetic resin and rubber adhesives category accounts for about 70 percent of the value of shipments with the remainder split between the other two categories.

Manufacturing Processes--

The manufacturing processes vary with raw materials and type of product.

Natural-Base Glues and Adhesives--The natural-base glues include animal glues (hide, bone), protein adhesives (casein, blood, fish, soybean), vegetable adhesives (starches, dextrins), and bituminous cements. In the manufacture of animal glues the general process consists of cleaning the hide or bones, extraction with hot water or steam, filtration, evaporation and drying. Figures 26 and 27 present the processes in more detail.

Casein is prepared by acidifying skimmed milk to pH 4.5 to precipitate the solid curd from the liquid (Figure 28). The curd is washed, dried and ground. Casein adhesives are prepared using alkali dispersing agents and other additives such as preservatives, plasticizers, viscosity-control agents, and fillers.

To prepare fish glue, selected fish skins are washed free of preservative (salt) and cooked with hot water to extract the protein (5-7 percent solids), filtered, and concentrated to 40 to 50 percent solids. A preservative is added to the adhesive (Figure 29).

Soybean flour is prepared from dehulled, extracted, and dried soybeans keeping the temperature below about 160 F to preserve the solubility of soybean protein. Soybean flour is mixed just before use with compounds to aid wetting, dispersion, defoaming and optionally crosslinking, blending adhesive resins, and fillers.

Blood glues are prepared from fresh liquid blood collected in packing plants. The clotting substance is removed, preservatives added, and the liquid spray-dried or vacuum dried at carefully controlled temperatures.

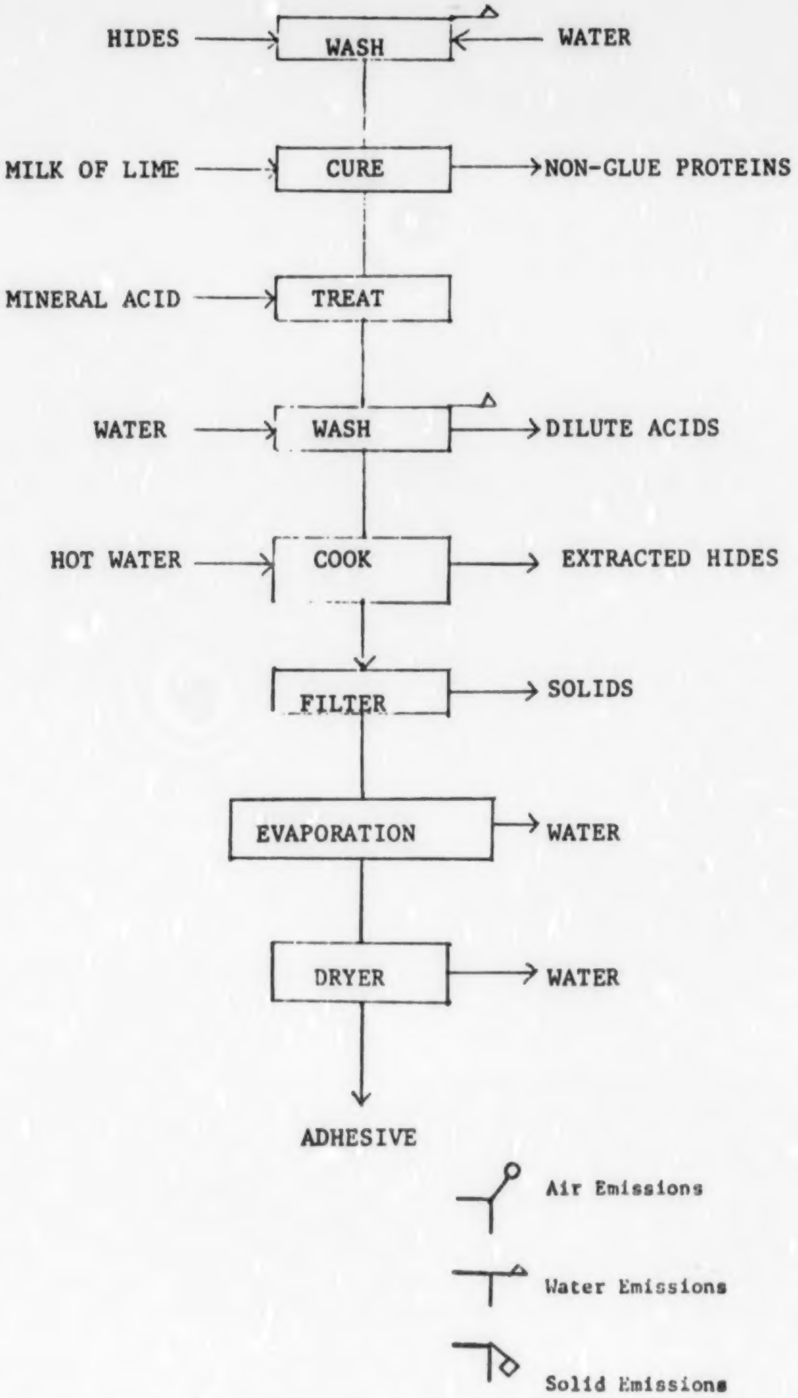

HIDES
WASH
WATER
MILK OF LIME
CURE
NON-GLUE PROTEINS
MINERAL ACID
TREAT
WATER
WASH
DILUTE ACIDS
HOT WATER
COOK
EXTRACTED HIDES
FILTER
SOLIDS
EVAPORATION
WATER
DRYER
WATER
ADHESIVE
Air Emissions
Water Emissions
Solid Emissions

FIGURE 26. HIDE GLUE MANUFACTURE.

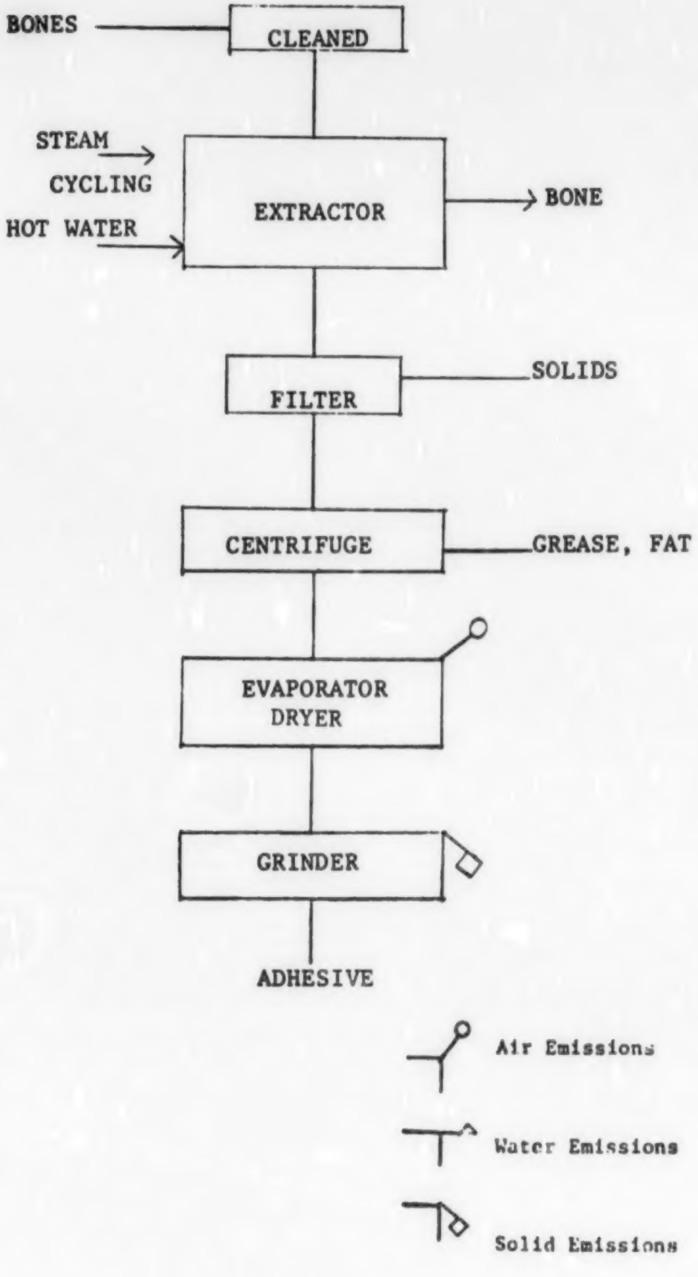
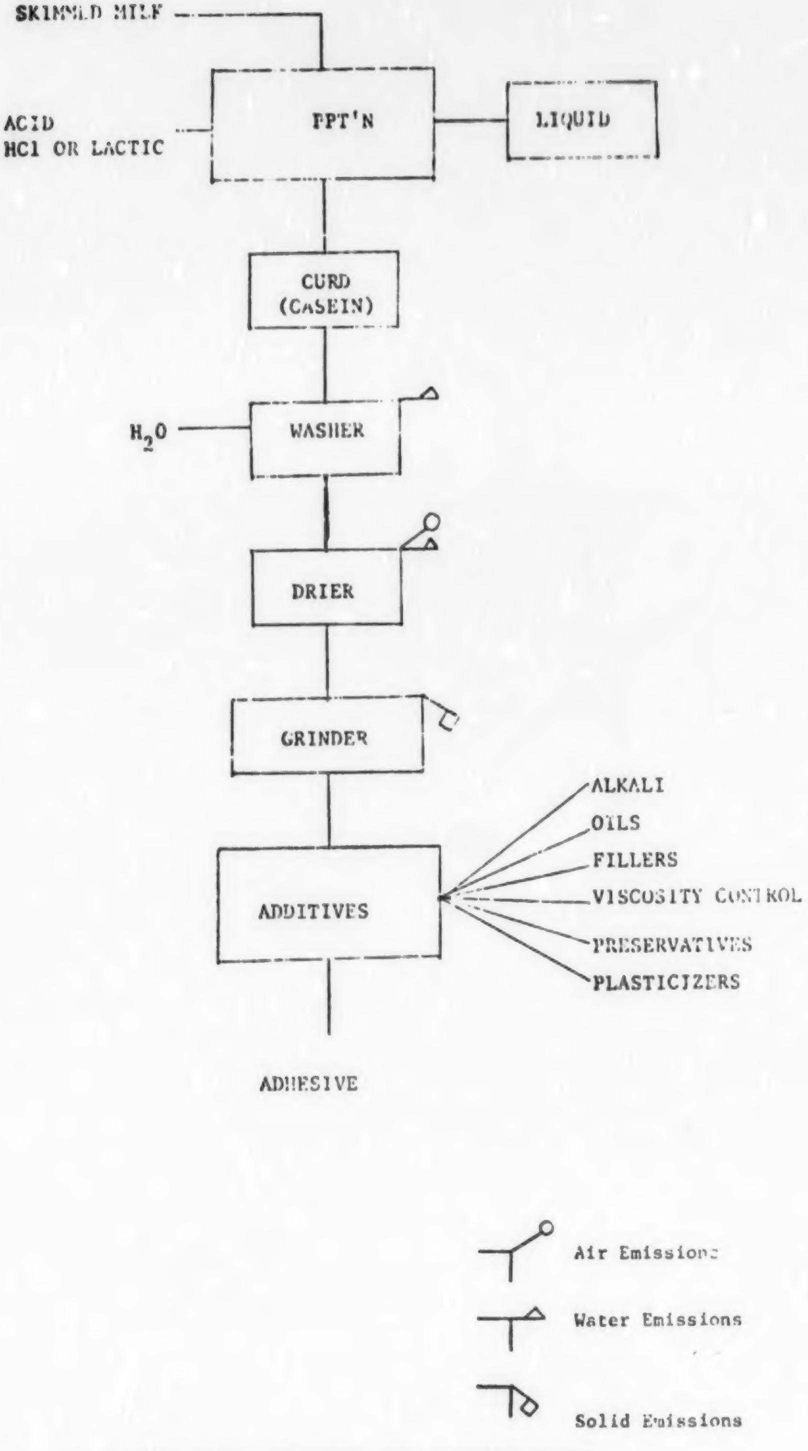

BONES
CLEANED
STEAM
CYCLING
HOT WATER
EXTRACTOR
BONE
FILTER
SOLIDS
CENTRIFUGE
GREASE, FAT
EVAPORATOR DRYER
GRINDER
ADHESIVE
Air Emissions
Water Emissions
Solid Emissions

FIGURE 27. BONE GLUE MANUFACTURE.



SKIMMED MILK
ACID
HCl OR LACTIC
PPT'N
LIQUID
CURD
(CASEIN)
H_2O
WASHER
DRIER
GRINDER
ADDITIVES
ALKALI
OILS
FILLERS
VISCOSITY CONTROL
PRESERVATIVES
PLASTICIZERS
ADHESIVE
Air Emissions
Water Emissions
Solid Emissions

FIGURE 28. MANUFACTURING PROCESS FOR CASEIN GLUE.

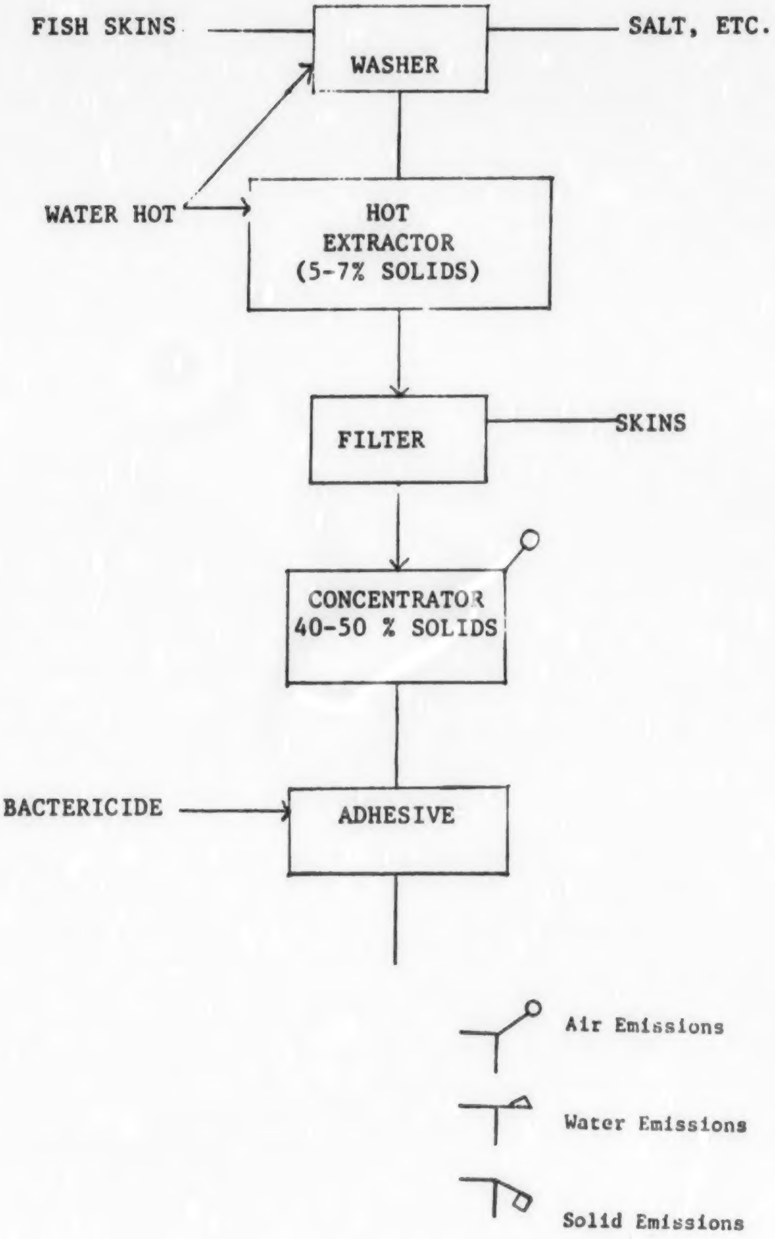

FISH SKINS
WASHER
SALT, ETC.
WATER HOT
HOT EXTRACTOR (5-7% SOLIDS)
FILTER
SKINS
CONCENTRATOR 40-50 % SOLIDS
BACTERICIDE
ADHESIVE
Air Emissions
Water Emissions
Solid Emissions

FIGURE 29. FISH GLUE PROCESSING.

Soluble and partly soluble blood is used for adhesives with appropriate additives and fillers.

Starch (corn, potato, wheat, and tapioca) can be degraded inexpensively into a wide range of adhesive products including thin-boiling starches, oxidized starches and dextrins. Aqueous dispersions of these materials with dispersing aids, defoamers, fillers, etc. are widely used adhesive systems.

Synthetic Resin and Rubber Adhesives--The range of raw materials for synthetic resin and rubber-based adhesives include essentially all types or organic polymeric compounds. Table 2 lists the chief base materials for adhesives. Obviously, it is extremely difficult to make general statements concerning emissions and waste streams. Table 3 presents types of materials used as compounding ingredients in adhesives. This also covers a wide range of chemical compounds.

In general, the adhesives are manufactured as water dispersions or solutions, solutions in organic solvents, or as solvent-free semisolid or solid products. Water-dispersed adhesives may be formed by emulsion polymerization of the base material or dispersion of pre-polymerized material in water. Figure 30 presents a flow chart of these processes. Solvent systems are prepared by dissolving the adhesive compound or compounds in an organic solvent. The physical properties of the raw material and the viscosity of the product dictate the type of equipment necessary. Low-viscosity resins can use low-shear, high-speed stirrers while high-viscosity products may require high-shear mills to produce solutions. Hot-melt adhesives may be prepared by hot milling ingredients and cooling the product. Figure 31 outlines the steps in preparing synthetic resin-based adhesives. Rubber-based adhesives may require milling of the rubber between steel rolls at room temperature or elevated temperatures. This softens the rubber and renders it more soluble.

Sealants are made from elastomeric materials, either alone or with pigments and solvents. Many types of sealants have been developed to solve specific problems. The physical properties of the sealant are varied by varying the elastomer (high or low molecular weight compounds), pigment (powder, fibrous, platelike), and sometimes solvents. Sealants are formulated for gun or knife application and (with solvents) brush or spray. Manufacturing processes for sealants are similar to those for adhesives, that is, the elastomers are blended with additives such as plasticizers and pigments then diluted with solvents, if required.

Waste Streams--

Natural-base adhesives processing presents the possibility of generating volatile material during the digestion steps. Usually there is solid waste (unextractable portion of bones, hides, etc.). These are usually processed further into by-products such as fertilizer. Cleanup of processing equipment may result in waterborne waste.

TABLE 2. MATERIALS FOR SYNTHETIC RESIN AND RUBBER ADHESIVES

Thermoplastic Adhesives

- Acrylate-vinyl acetate
- Acrylic-ethylene
- Acrylonitrile-butadiene-styrene
- Cellulose acetate
- Cellulose acetate butyrate
- Cellulose caprate
- Cellulose nitrate
- Chlorinated polyethylene
- yanoacrylate
- Ethyl cellulose
- Hydroxyethyl cellulose
- Methyl cellulose
- Polyacrylate
- Polyacrylic esters
- Polyamide
- Polyester
- Polyether
- Polyimide
- Polymethacrylate
- Polystyrene
- Polysulfone
- Polyvinyl acetal
- Polyvinyl acetate
- Polyvinyl alcohol
- Polyvinyl butyral
- Polyvinyl chloride
- Polyvinyl formal
- Vinyl acetate-ethylene
- Vinyl chloride-vinyl acetate
- Vinyl chloride-vinylidene

Thermosetting Adhesives

- Epoxy
- Epoxy ester
- Epoxy/bitumen
- Furan
- Melamine formaldehyde
- Phenol formaldehyde
- Phenol formaldehyde-resorcinol
- Phenolic
- Phenolic-epoxy
- Polyester
- Polyethylene imine
- Polyisocyanate
- Polyurethane
- Resorcinol formaldehyde
- Silicone
- Urea formaldehyde

Rubber-Based Adhesives

- Butadiene acrylonitrile rubber
- Butadiene-polyacrylate rubber
- Butadiene-styrene rubber
- Butyl rubber
- Chlorinated rubber
- Cyclized rubber
- Depolymerized rubber
- Natural rubber
- Polybutadiene
- Polychloroprene
- Polyisobutylene
- Polyisoprene
- Polysulfide
- Polyurethane rubber
- Reclaimed rubber
- Silicone rubber

Hot-Melt Adhesive

- Polyamides
- Polycarbonates
- Polyesters
- Polyolefins
- Polyvinyl acetate

TABLE 3. ADHESIVE CHEMICALS AND COMPOUNDING INGREDIENTS

Accelerating and vulcanizing agents
Antioxidants
Bleaches
Collodial stabilizers
Crosslinking and insolubilizing agents
Defoamers
Dyes and pigments
Extenders and fillers
Humectants
Liquifiers
Perfuming and masking agents
Plasticizers
Preservatives
Softners
Solvents
Tackifiers
Thickeners
Ultra-violet absorbers
Wetting agents
Miscellaneous chemicals

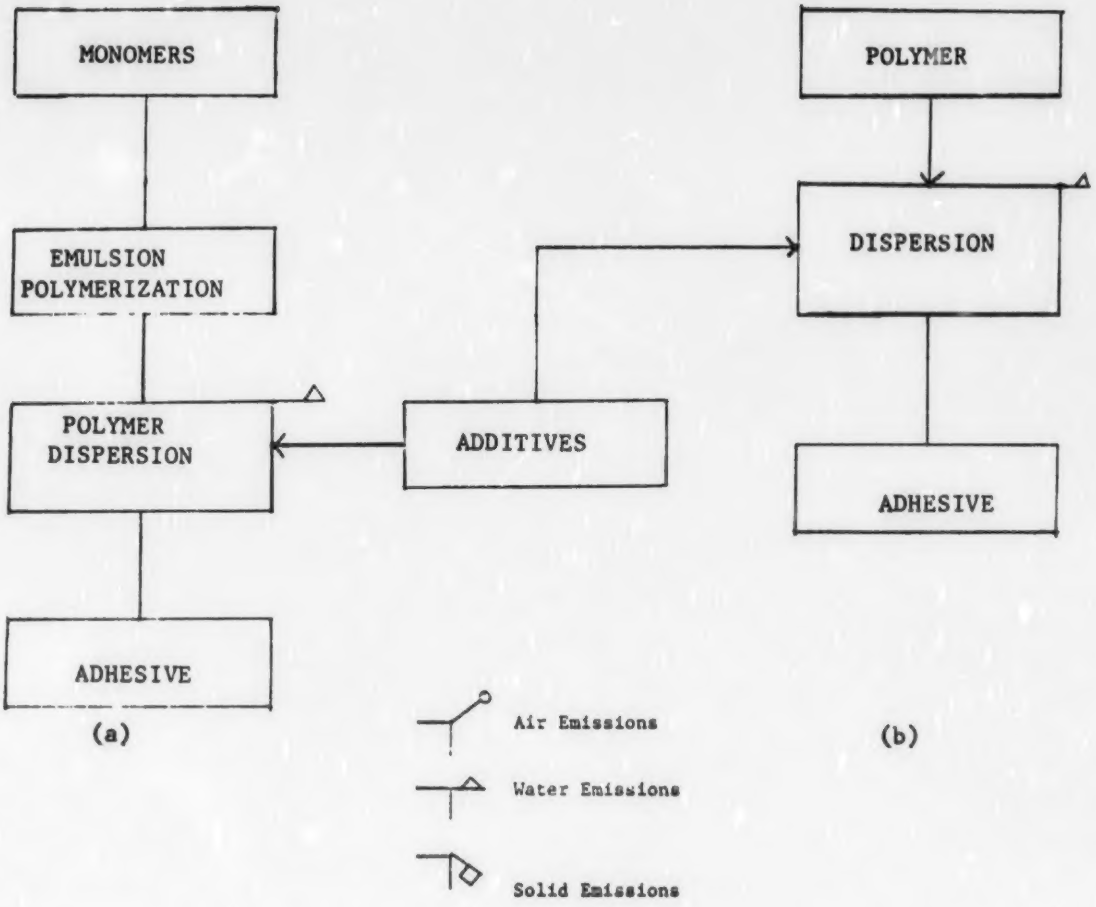

MONOMERS
EMULSION POLYMERIZATION
POLYMER DISPERSION
ADDITIVES
ADHESIVE
(a)
POLYMER
DISPERSION
ADHESIVE
(b)
Air Emissions
Water Emissions
Solid Emissions

FIGURE 30. WATERBASED ADHESIVES; (A) EMULSION POLYMERIZATION AND (B) DISPERSION PROCESSES.

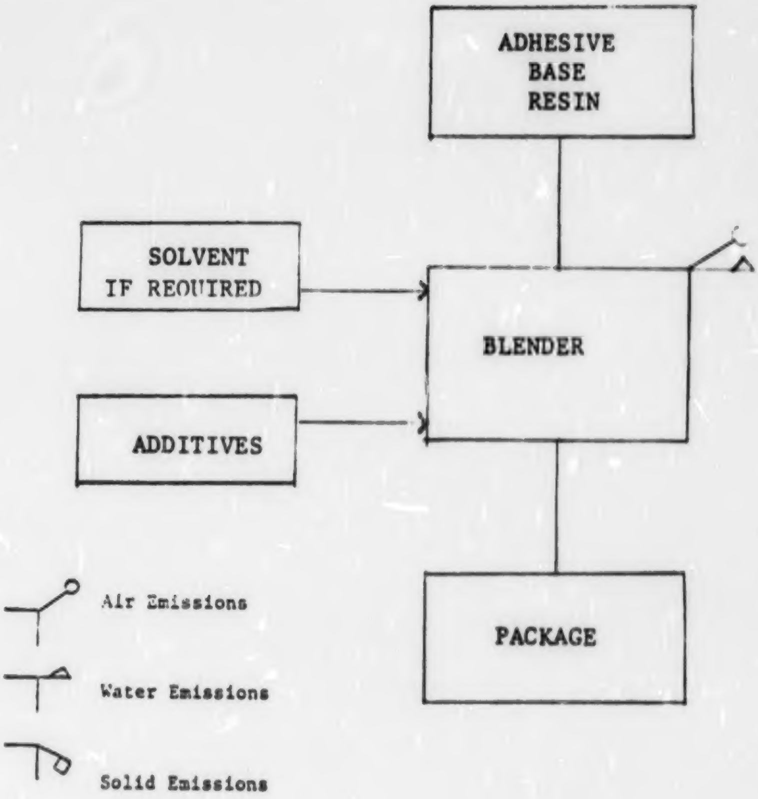

ADHESIVE BASE RESIN
SOLVENT IF REQUIRED
BLENDER
ADDITIVES
PACKAGE
Air Emissions
Water Emissions
Solid Emissions

FIGURE 31. SYNTHETIC RESIN AND RUBBER BASE ADHESIVES.

Often the raw materials for synthetic resin and rubber-based adhesives are manufactured at a site other than the adhesive formulation installation. In this case the manufacturing process consists essentially of dissolution and blending ingredients and packaging the resultant mixture. There may be volatile components of the resins and the volatile organic solvents used present possible emissions to be controlled. If fillers such as clay are used, particulate emissions may be a problem. Liquid waste may be generated in clean-up operations. Wastewaters from synthetic resin and rubber based products contain high dissolved solids, heavy metals, total suspended solids, BOD, COD, and hexane extractibles.

Specific statements for the industry as a whole are difficult because of the very wide range of chemical compounds used as base materials and additives. Some manufacturers produce a wide range of products while others produce only one type with possibly several grades.

Printing Ink

This industry consists of establishments primarily engaged in manufacturing of the following types of inks:

Bronze ink
Gold ink
Gravure ink
Ink, duplicating
Ink, printing: base or finished
Lithographic ink
Printing ink
Screen process ink.

The ink manufacturing industry is similar to the paint industry in that it is essentially a formulation industry.

Printing ink production in the United States now exceeds one billion pounds per year. The industry comprises over 250 printing ink producers. However, seven companies share over 50 percent of the market: Inmont, Sinclair and Valentine, Sun Chemical, Cities Service (F. H. Levey), Tenneco Chemicals (California Ink), Bordon, and Flint Ink. Many large-volume users are captive producers as, for example, American Can, Reuben H. Donnelly, Bemis Bag and others.(11)

Manufacturing Processes--

Both oil- and water-base inks can be made in the same factory. Many of the same raw materials are used and the inks are produced with, generally, the same equipment. Some oil-base pigments may be blended into the extenders and carriers before being dispersed by roll or ball mills. The various oils and resins, lacquers, clays, pigments, and dispersing agents used are generally the same. The major difference is the use of either oil or water as the dispersing medium. The production of ink products consists of milling, dispersion and mixing operations.

The processes and equipment used by the ink industry are very similar to those used by the paint industry and will not be discussed here.

Figure 32 shows a typical flow diagram for the ink industry.

Waste Streams--

Solvent vapor emissions occur in almost every phase of manufacturing and in numerous locations throughout individual plants. Typical emission points are:

Blending tanks
Grinding
Dispersion
Holding tanks
Filtering
Packaging
Storage tanks.

The loading or unloading of pigments and other dry solid into grinding and dispersion equipment results in dust emission into the surrounding plant areas.

The only process wastewater from ink formulation is the water used for tubwashing. However, sometimes this water is recycled and the sludge is transported to landfills.

Fireworks and Pyrotechnics Industry

This industry consists of establishments manufacturing a wide array of pyrotechnic items and fireworks for military and civilian uses. Military pyrotechnics include light effects for illumination and signalling (flares), smoke, noisemakers, and specialized heat sources. Civilian pyrotechnics comprise all types of fireworks, railroad and highway fuses, railroad torpedoes, and specialized heating devices. The scope of this industry varies widely from, for example, toy caps to 2-million-candlepower illuminating flares. This industry appears to depend on empirical, practical, and proprietary processes and formulations. According to the 1972 Census of Manufacturers, the industry annually ships products worth about $40 million.(1) Thomas Register 1976 lists 36 companies engaged in one or more parts of this industry.

Manufacturing Processes (13,14)--

The manufacture of pyrotechnics is a hazardous industry and adherence to safety regulations is of utmost importance.

The overall process involves formulation of the pyrochemicals and assembling the pyrotechnical material within the container or package (Figure 33). The complexity of the finished device varies from paper caps (small powder charge between paper layers) to display fireworks with numerous charges of different composition and complex fusing arrangement to control

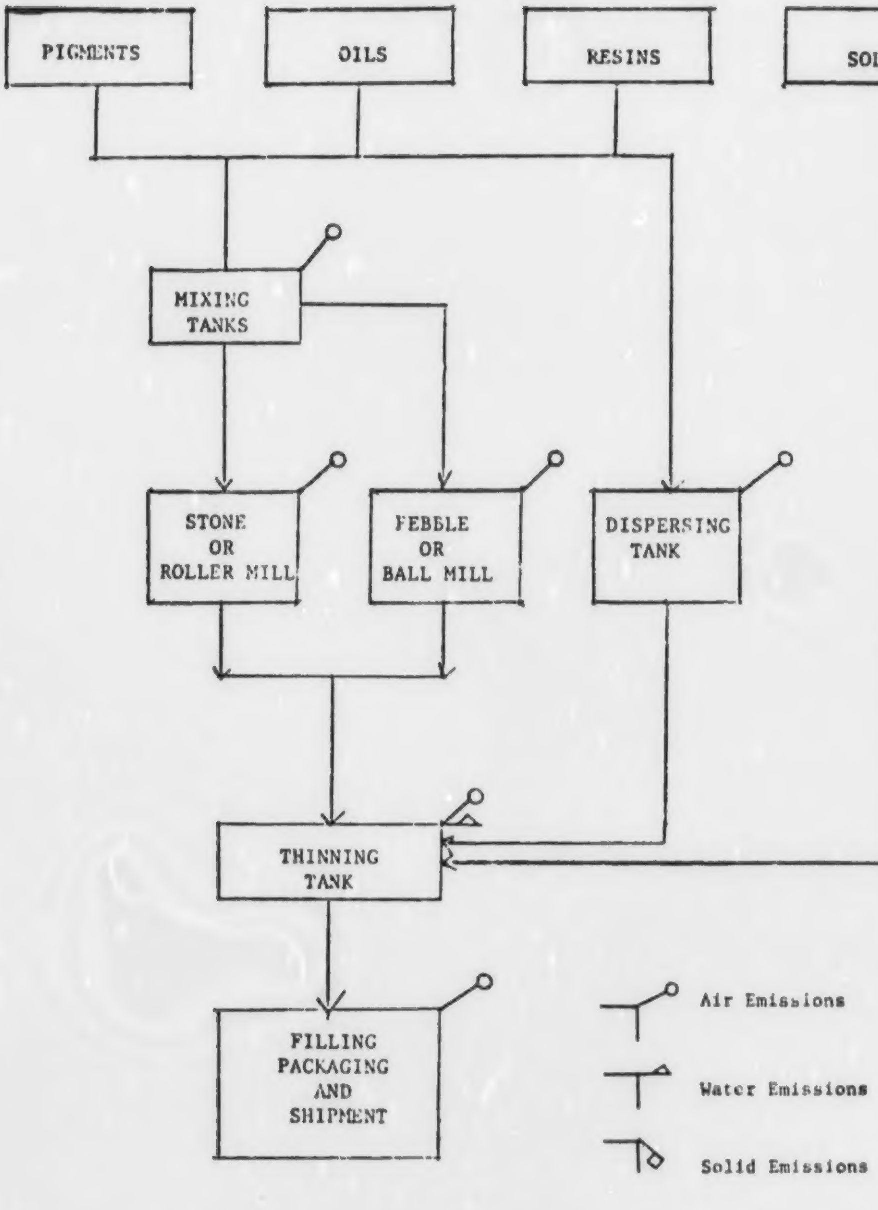

PIGMENTS
OILS
RESINS
SOLVENT
MIXING TANKS
STONE OR ROLLER MILL
PEBBLE OR BALL MILL
DISPERSING TANK
THINNING TANK
FILLING PACKAGING AND SHIPMENT
Air Emissions
Water Emissions
Solid Emissions

FIGURE 32. GENERAL FLOW DIAGRAM FOR THE FORMULATION OF OIL-BASE INK.(12)

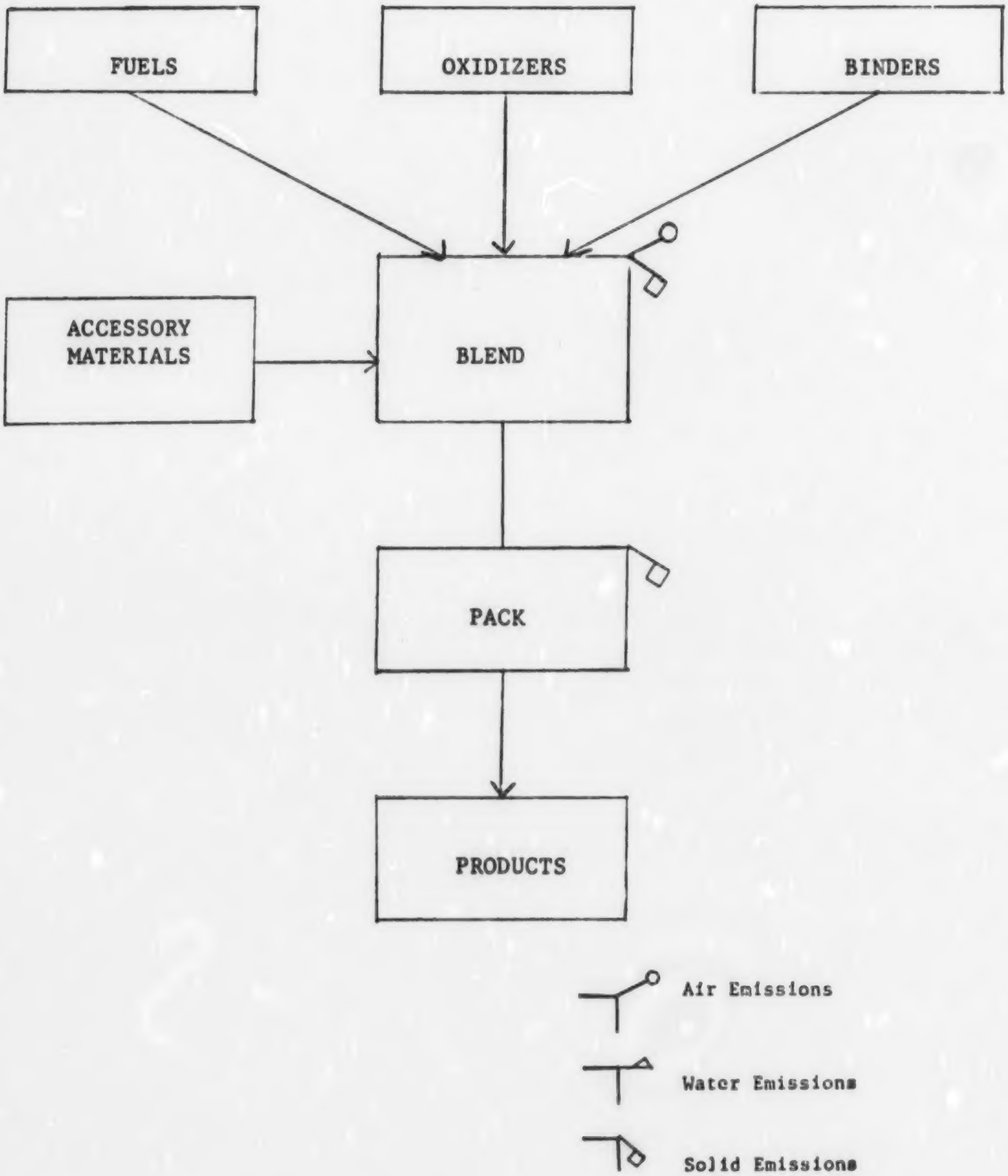

FUELS
OXIDIZERS
BINDERS
ACCESSORY MATERIALS
BLEND
PACK
PRODUCTS
Air Emissions
Water Emissions
Solid Emissions

FIGURE 33. FLOW DIAGRAM OF MANUFACTURING FIREWORKS AND PYROTECHNIC MATERIALS.

ignition and propulsion for desired effects. Complex timing devices that result in the ejection of the pilot from aircraft or separation systems in astronautics are examples of sophisticated pyrotechnic applications.

Formulation of the pyrochemical materials consists of blending combinations of the following items:

Fuels. Historically charcoal and sulfur, but now includes a large variety of materials such as metallic powders (magnesium, aluminum, iron, titanium, zirconium, manganese molybdenum, tungsten, lead, etc.); nonmetals, such as silicon and boron; and some organic materials such as gallic acid, picrates, carbohydrates, oils, and waxes.

Oxidizers. Nitrates of sodium, potassium, strontium, and barium; potassium chlorate and potassium perchlorate; fluorocarbon polymers; and hexachloroethane, etc.

Binders. Dextrins, gum arabic, cellulose nitrate, polyesters, shellac, etc.

Accessory Materials. Dry-flow control and mining aids, liquid desensitizers, moisture-barrier materials, and neutralizers.

Blending procedures depend on the texture and sensitivity of the resulting mixture. Loose powders are blended by simple tumbling or in a V-shaped tubular blender. Some mixtures require a more vigorous action with alternate squeezing and plowing as with a steel muller. The latter methods are used with formulations containing polymeric binders.

The pyrochemical mixture, ranging from loose powder to plastic mass, is then loaded into the final package or device. This varies from hand pouring to automatic metering for the loose materials. Other materials are packed into paper or metallic tubes, depending on the end product. The charges may be packed with light pressure to form pellets, cylindrical columns, or a long chain. Military devices may require high-pressure hydraulic forces to pack steel or brass tubes or molds. Hand packing or hydraulic presses are used depending upon degree of consolidation required and the degree of automation attained.

Most pyrotechnic items involve more than one compound of different chemical or physical properties. For example, an aerial display piece requires igniting fuse, propelling charge, fusing for secondary propulsion of "stars", colored or explosive charges, plus any special-effect charges. Details of these separate formulations and especially techniques for preparation are generally proprietary.

The processing of pyrotechnical materials is primarily dry with liquids used as volatile compounds or as processing aids and binders for forming solid masses of materials.

Waste Streams--

During compounding, dry materials are generally mixed in closed containers, often with wetting liquids to reduce sensitivity. Possible emissions consist of volatiles from organic liquids or binder solvents and solid particulate material from ingredients. The hazardous nature of these materials would seem to dictate that any loose material would be minimized.

During packing or loading, because of the hazardous nature of compounds, special care is taken to minimize material losses. Materials at this stage are essentially dry solids.

RUBBER AND MISCELLANEOUS PLASTICS PRODUCTS

The rubber-processing industry is a highly diversified one involving the synthesis of polymers as well as the fabrication of polymers and natural rubber into finished products. It is also quite fragmented; over 2000 plant locations have been identified. The segments of the rubber industry covered in this analysis consist of the following industries:

- Tire and inner tubes
- Rubber and plastics footwear
- Reclaimed rubber
- Rubber and plastics hose and belting
- Fabricated rubber products
- Retread tires.

The miscellaneous plastics products industry consists of 7,698 establishments, and employs 347,000 people, producing a wide diversity of products.

Tires and Inner Tubes

The tire and inner tube industry consists of 56 plants producing 172 million tires and 53 million inner tubes annually for a total rubber consumption of 2.5 million tons per year.(19) Tire and inner tube plants are located primarily in Ohio and southeastern U.S. A few are located in northern U.S. and the remainder are scattered widely throughout the country.

Manufacturing Processes--

The raw materials used in manufacturing tires consist of rubber (natural and synthetic), oil, fabric, wire, carbon black, and various additives such as antioxidants, antiozants, curing agents, and catalysts. Soapstone although not a raw material, is used extensively in the tire industry to prevent uncured rubber from sticking to itself. Soapstone comprises a major source of suspended solids in the effluent waste from tire plants.

The typical tire manufacturing process consists of the following:

1. Preparation or compounding of the raw materials
2. Transformation of these compounded materials into the five tire components
3. The building, molding, and curing of the final product.

A flow diagram for the typical plant is shown in Figure 34. The basic machinery units used in the compounding operation are the Banbury mixer and the roller mill. A Banbury mixer is a batch-type internal mixing device and is the hub of this compounding operation. After mixing, the compound is sheeted out in a roller mill, extruded into sheets, or pelletized. The process depends on the type of batch (reactive or non-reactive) and the manufacturer. Pelletizing of a non-reactive batch permits the weighing and mixing of the stock to be done automatically. The reactive compounded rubber is always sheeted out.

The rubber stock, once compounded and mixed, must be molded or transformed into the form of one of the final parts of the tire. This consists of several parallel processes by which the sheeted rubber and other raw materials, such as cord and fabric, are made into the following basic tire components: tire beads, tire treads, tire cords, and tire belt (fabric).

In the formation of tire treads, the rubber stock as it is received from the compounding section is manually fed to a warm-up roller mill. Here the rubber is heated and further mixed. Heat is provided by the conversion of mechanical energy. Temperature control is provided by the use of cooling water within the rolls of the mill.

To produce tire cords and belts, rubber stock must be impregnated onto a pretreated fabric. The fabric is led off a roll, spliced onto the tail of the previous roll (either adhesively or by a high-speed sewing machine), and fed under controlled tension (via a festooner) to a latex dip tank. After dipping and while still under tension, the fabric is fed past vacuum suction lines or rotating beater bars to remove the excess dip before the fabric rises through a drying and baking oven.

In the processing of rubber stock to tire beads, the rubber is extruded onto a series of copper-plated steel wires, which are then cemented, wrapped, and cut. The rubber stock is pretreated, as before, in a warm-up mill and strip-feed mill. Excess rubber is trimmed from the bead before it leaves the extruder and is fed back to the strip feed mills. To apply cement the coated wire is passed through a trough or set of brushes. The cement is necessary to insure the proper adhesion of the bead when it is wrapped.

The tire is molded and cured in an automatic press. Here a rubber bladder bag is inflated inside the tire, causing the tire to take its characteristic doughnut shape. The mold is simultaneously closed over the shaped tire. Heat is applied by steam via the mold and bladder bag. Excess rubber

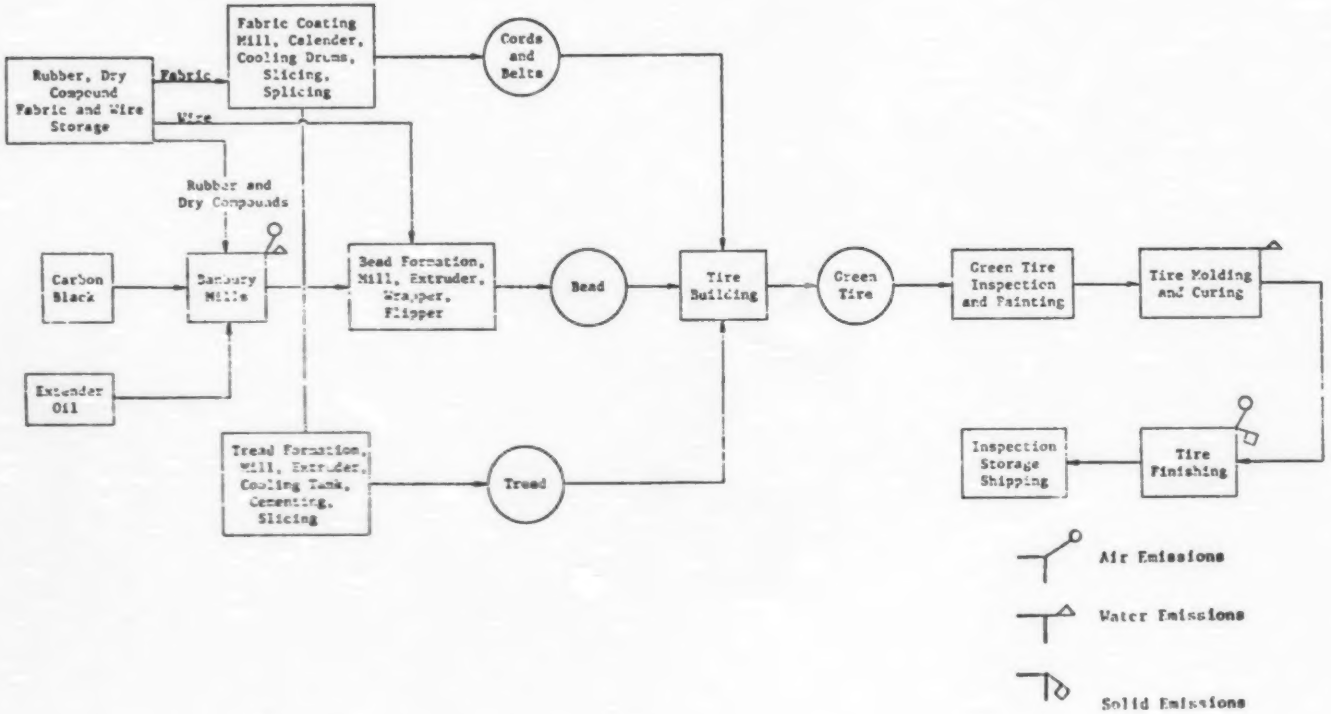

Rubber, Dry Compound Fabric and Wire Storage
Fabric
Wire
Rubber and Dry Compounds
Fabric Coating Mill, Calender, Cooling Drums, Slicing, Splicing
Cords and Belts
Carbon Black
Banbury Mills
Extender Oil
Bead Formation, Mill, Extruder, Wrapper, Flipper
Bead
Tread Formation, Mill, Extruder, Cooling Tank, Cementing, Slicing
Tread
Tire Building
Green Tire
Green Tire Inspection and Painting
Tire Molding and Curing
Tire Finishing
Inspection Storage Shipping
Air Emissions
Water Emissions
Solid Emissions

FIGURE 34. DIAGRAM FOR TYPICAL TIRE AND CAMELBACK PRODUCTION FACILITY.

Source: Tire and Synthetic, EPA 440/1-73/013.(20)

and trapped air escape through weepholes. After a timed, temperature-controlled cure, the press is cooled, the bladder is deflated via a vacuum, and the tire is removed. The tire is next inflated with air and left to cool in the atmosphere. This last inflation insures product quality and uniformity by allowing the tire to "set up" or achieve the final limits of its cure under controlled conditions.

After the molding and curing operations, the tire proceeds to the grinding operation where the excess rubber which escaped through the weepholes is ground off. If the tire is designated to be a whitewall, additional grinding is performed to remove a black protective strip. Most tires receive further grinding of the tread in order to balance the tire.

After the grinding operations, the whitewall portion of a tire receives a protective coat of paint. The paint is generally water based. This operation usually occurs in a hooded area. Solids from any wet air pollution equipment or runoff due to overspraying of the paint will create pollution problems. After inspection and possibly some final repairs, the tire is ready to be shipped.

Waste Streams--

Table 4 presents a review of the potential sources of wastewater streams. Air emissions result from the compounding, green tire printing, and tire finishing operations. Solid waste results from the grinding operations.

Manufacturing Processes--

Inner tube manufacturing is very similar to tire manufacturing in that the process consists of the following steps:

1. Preparation or compounding of raw materials
2. The extension or compounding of raw material to form a tube
3. The building, molding and curing to form the final products.

A flow diagram for the typical process is shown in Figure 35.

The basic machinery used in the compounding operation is similar to that used in tire manufacturing, namely, Banbury mixers and roller mills.

Waste Streams--

Pollutants are emitted by the Banbury mills operation when carbon black is added to the mill.

TABLE 4. SUMMARY OF POTENTIAL PROCESS-ASSOCIATED WASTEWATER

Plant Area	Source	Nature and Origin of Wastewater Contaminants
Oil storage	Run off	Oil
Compounding	Washdown, spills, leaks, discharges from wet air-pollution equipment	Solids from soapstone dip tank Oil from seals in roller mills Oil and solids from Banbury seals Solids from air-pollution equipment discharge
Bead, tread, tube formation	Washdown, spills, leaks	Oil and solvent-based cements from the cementing operation Oil from seals in roller mills
Cord and belt formation	Washdown, spills, leaks	Organics and solids from dipping operation Oil from seals in roller mills, calenders, etc.
Green tire painting	Washdown, spills, air-pollution equipment	Organics and solids from spray-painting operation Soluble organics and solids from air pollution-equipment discharge
Molding and curing	Washdown, leaks	Oil from hydraulic system Oil from presses
Tire finishing	Washdown, spills, air-pollution equipment	Solids and soluble organics from painting operation Solids from air-pollution equipment discharge

SOURCE: Tire and Synthetic Segment, EPA 440/1-73/013(20)

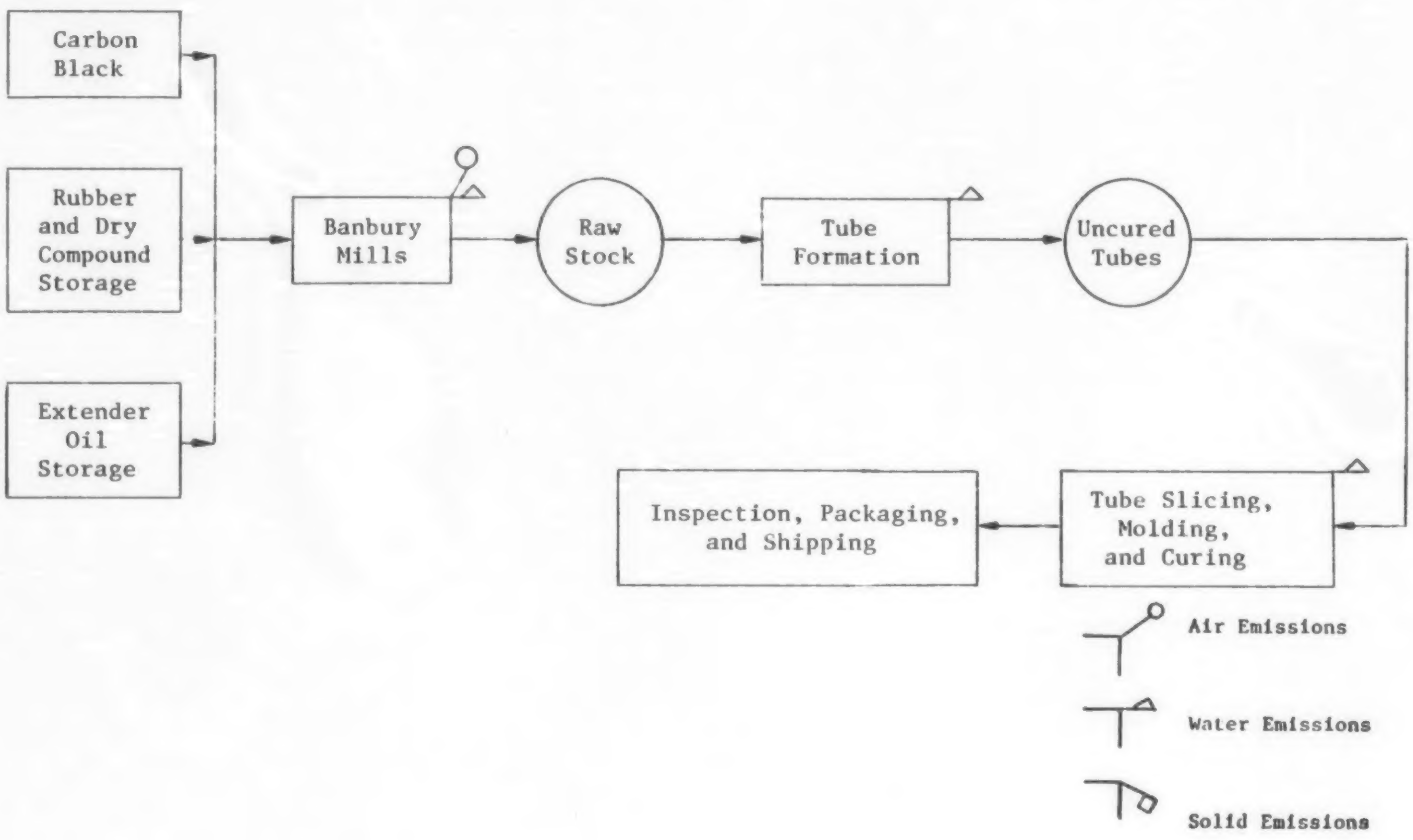

Carbon Black
Rubber and Dry Compound Storage
Extender Oil Storage
Banbury Mills
Raw Stock
Tube Formation
Uncured Tubes
Tube Slicing, Molding, and Curing
Inspection, Packaging, and Shipping
Air Emissions
Water Emissions
Solid Emissions

FIGURE 35. FLOW DIAGRAM OF A TYPICAL INNER TUBE PRODUCTION FACILITY.

Source: Tire and Synthetic Segment, EPA 440/1-73/013 (20).

Rubber Hose and Belting

This industry consists of establishments engaged primarily in the manufacture of rubber hose and belting, including garden hose. The establishments that manufacture these products include the major rubber companies and several others. At present 68 companies manufacture hose and belting. Many of the companies manufacture mechanical goods in the same plant. In 1972, 90 establishments in this industry shipped products valued at $1.02 billion and employed 31,900 persons.(1)

Manufacturing Processes--

Hose manufacture can be classified according to the manner in which the hose is produced. Such factors as service, size, production volume, and cost usually determine the method by which the hose is made. The greatest proportion of all hose manufactured today is produced by highly mechanized equipment specially designed for the purpose. Three fundamental methods of hose manufacture exist, producing the following types of hose:(21)

1. Machine-wrapped ply hose
2. Hand-built hose
3. Braided and spiralled hose.

Hand-Built Hose--The term hand-built hose applies to two general types of hose, non-wire reinforced and wire reinforced, which are made by hand on a steel mandrel. The hose is made by hand when it is too large in diameter, too long to fit in the three-roll making-machine, or when the hose is made with special ends. The hand method is also used frequently when the fabric reinforcement must be applied one ply at a time. The mandrel is mounted on a series of double roller stands and one end of the mandrel is held in the jaws of a powerdriven chuck to rotate the mandrel during the making operations.

Braided and Spiralled Hose--The term braided hose identifies a type of hose construction and method of manufacture in which the strands of reinforcement are interlaced or interwoven in addition to spiralling around the tube. Braided hose is produced in size ranging from 5 to 200 millimeters (0.2 to 8 inches) internal diameter. A variety of methods are available for manufacture. Factors such as internal diameter, length, burst strength, production rate, and cost dictate to a large extent how the hose is made.

Manufacturing commences with the extrusion of a tube supported on a flexible mandrel or a non-supported tube in lengths up to 50 meters (165 feet) or in continuous lengths. Non-supported tube must be firm enough in the unvulcanized state to resist deformation and stretching under normal processing conditions. A high percentage of braided hose is made with a non-supported tube. When the tube is too thin or too soft to withstand subsequent processing or when the internal diameter must be kept within a narrow range, it is supported on a flexible mandrel. The mandrel is at least as long as the hose to be made, has a round cross-section, and can be coiled in a small diameter. It is made of rubber or plastic material and may have a wire core to prevent stretching.

Belting--The other major product in this industry is belting. Compounding is carried out inthe conventional manner as in tire plants. The compounded rubber is then calendered onto fabric and cured in an autoclave or by continuous cure. V-belts are made on special equipment. They have wire reinforcement centers and are covered with rubberized fabric. The rubber is mixed by standard methods, i.e., in intensive mixers. The stock is then calendered onto fabric, slit, and wrapped on wire by means of special equipment.

Waste Streams--

Table 5 shows the origin of the wastewater from the production of rubber hose and belting. Air emissions result from the compounding operations.

Fabricated Rubber Products

This industry consists of establishments primarily engaged in manufacturing industrial and mechanical rubber goods, rubberized fabrics and vulcanized rubber clothing, and miscellaneous rubber specialties and sundries. In 1972 there were 1,103 establishments, employing 99,000 persons, which shipped products valued at $2.83 billion.(1)

Manufacturing Processes--

Processes employed in this industry segment are varied. Processes used are compounding, milling, fabrication, molding, vulcanization, and extrusion. The manufacture of molded rubber products is representative of the process in this industry.

Several methods are used to mold rubber products. The selection of a particular molding technique is dependent on the nature of the product, the type of rubber, and production economics. The principal methods used for the manufacture of general molded products are the compression, transfer, and injection-molding processes. In many cases all three techniques are used at one plant location.

Rubber molding processes typically consist of the following:(20)

1. Compounding of the rubber stock
2. Preparation of the mold preforms or blanks
3. Molding
4. Deflashing.

Compression Molding--Compression molding is the oldest method of making molded parts. The uncured rubber is formed to the approximate shape, referred to as a preform, and placed in the individual cavities of the mold.

TABLE 5. PROCESS-ASSOCIATED WASTEWATER SOURCES FROM THE PRODUCTION OF RUBBER HOSE AND BELTING

Plant Unit or Area	Source	Nature and Origin of Waste Water Contaminants
Oil storage	Spills and leaks	Oil pick-up by storm run-off
Compounding	Washdown, spills, leaks, and discharges from wet air-pollution control equipment	Solids from soapstone dip tank. Oil and water leaks from mixers and mills. Solids from wet air-pollution control equipment discharges.
Extrusion	Cooling waters, spoils, and leakages	Anti-tack agent in cooling tank overflows, oil from machinery
Calendering	Spills and leaks	Solids from soapstone dip tank. Oil and water leaks from mixers and mills
Curing(a)	Condensate	Organics and lead leached by steam vulcanizer condensate
Testing(b)	Spills and leaks	Oil pick-up hydraulic testing water

(a) Waste waters generated by curing operations are essentially limited to hose manufacture.

(b) Testing waters are used only in hose manufacture.

Source: Fabricated and Reclaimed Rubber, EPA 440/1-74/030(21).

As the mold is closed under pressure, the compound conforms to the shape of the cavity and the excess material is forced out into a flash groove.

Transfer Molding--Transfer molding involves the transfer of the uncured rubber stock from one part of the mold to another. The stock, in the form of blanks, is placed in a recess called the pot or transfer cavity. The pot is fitted with a ram or piston which is inserted over the stock. The force of the press when applied to the ram plus the heat from the mold causes the stock to be softened and flow through runners into the previously empty molding cavities, where the stock is cured in the desired form.

Injection Molding--Injection molding is the newest method of molding and requires the greatest degree of sophistication both from the standpoint of materials and mold design. Basically, it is the same as transfer molding with the exception that the stock is injected into the cavities. There are essentially three different types of injection-molding machines. One machine uses a ram to force the stock through runners into the cavities; another uses a screw; the third is a combination of the first two and is a reciprocating screw. Figure 36 shows a typical flow diagram for a molded item.

Waste Streams--

Airborne particles generated during the compounding operations are controlled by wet-scrubbing devices. Solid waste is generated during deflashing operations. When metal-bonded items are produced, the metal is degreased with a solvent and sometimes the metals are pickled. The spent degreasing solvent is generally drummed and hauled from the plant, while the pickle liquor requires containerization or treatment before it is discharged.

Tire Retreading

Tire retreading is an industry dominated by independents. Approximately 4,500 retreading shops or plants are currently registered with the Federal Department of Transportation and the number of tires retreaded by the industry as a whole approaches 32 million each year.(21) There are a few large retreading plants which are operated by the major tire companies: Firestone, Goodyear, Goodrich, and General, etc. In most aspects these are very comparable to a plant manufacturing new tires. An average retreading requires approximately 10 pounds of rubber per passenger tire and 35 pounds per truck tire.

Manufacturing Processes--

Figure 37 shows a typical tire-retreading operation. The majority of retreading shops purchase the rubber stock from an outside supplier in the form of camelback tread or extruded spaghetti rubber. The work tire is first visually inspected to ascertain its suitability for retreading. The satisfactory worn tire is first ground and buffed with a grinding wheel to remove the old, worn tread rubber. The buffing is stopped when the tire carcass is reached.

The bare carcass is coated with rubber cement and the camelback tread or

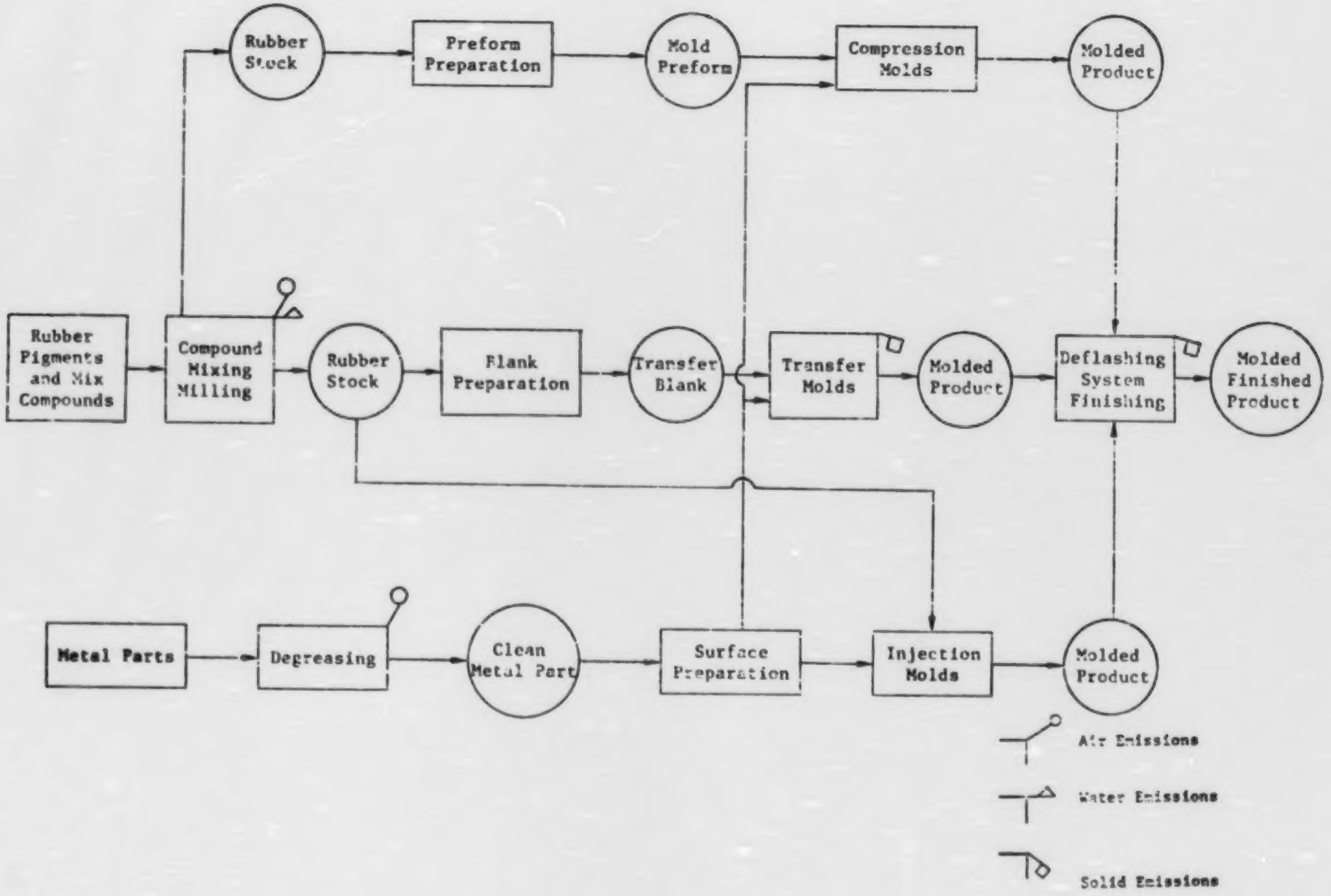

Rubber Pigments and Mix Compounds
Compound Mixing Milling
Rubber Stock
Preform Preparation
Mold Preform
Compression Molds
Molded Product
Rubber Stock
Blank Preparation
Transfer Blank
Transfer Molds
Molded Product
Deflashing System Finishing
Molded Finished Product
Metal Parts
Degreasing
Clean Metal Part
Surface Preparation
Injection Molds
Molded Product
Air Emissions
Water Emissions
Solid Emissions

FIGURE 36. FLOW DIAGRAM FOR PRODUCTION OF A TYPICAL MOLDED ITEM.

Source: Fabricated and Reclaimed Rubber, EPA 440/1-74/030.(21)

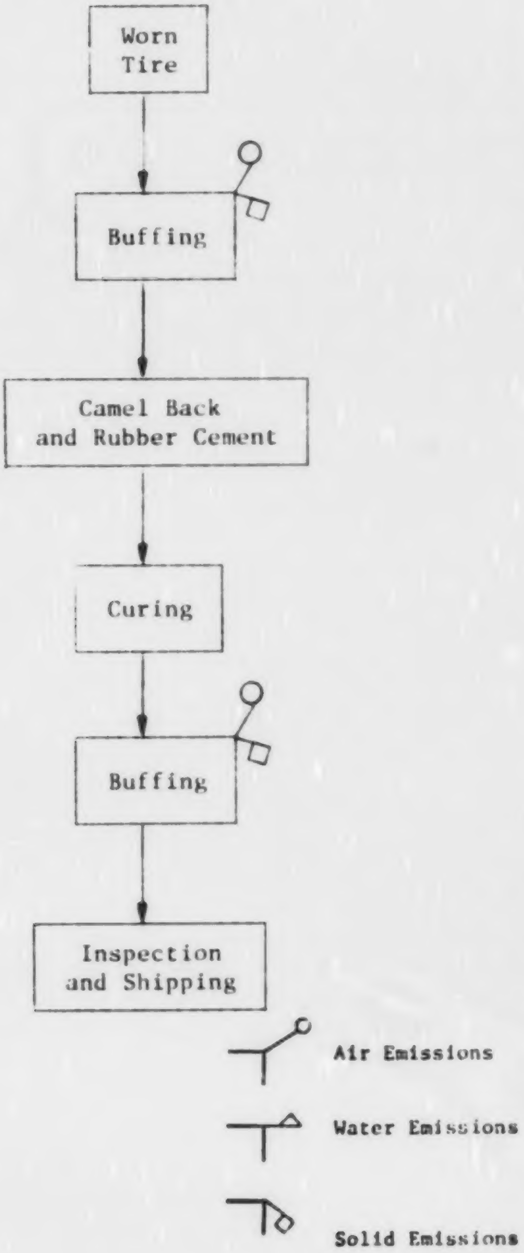

Worn Tire
Buffing
Camel Back and Rubber Cement
Curing
Buffing
Inspection and Shipping
Air Emissions
Water Emissions
Solid Emissions

FIGURE 37. FLOW DIAGRAM OF A RETREAD OPERATION.

spaghetti rubber is applied around the tire and cut to length. The tire with tread rubber is placed in the curing mold and the mold is closed. Most of the curing molds are steam heated and the steam condensate is recycled to the boiler. Some molds are heated with electricity; these are generally older than the steam-heated molds.

After curing, the tire is removed from the mold. The rubber flash is buffed off the tire before it is inspected and shipped.

Waste Streams--

Solid waste is generated by the buffing and grinding operations and the fine buffings are emitted into the air. Worn tires that are found unsuitable for retreading are removed from the shop as solid waste.

Reclaimed Rubber

The category includes establishments which are engaged primarily in reclaiming rubber from scrap rubber tires, tubes, and miscellaneous waste rubber articles by processes which result in devulcanization, depolymerization, or regeneration of products that contain added ingredients. These products are sold for use as raw materials in the manufacture of rubber goods, sometimes mixed with crude or synthetic rubber, sometimes not.

The quantity of scrap rubber being reclaimed and reused and the number of rubber reclaiming plants operating in the United States have both steadily declined over the past decade. Some of this reduction is probably due to development of new rubbers not compatible with reclaimed rubber, but the major decreases are undoubtedly the result of cost, quality, and environmental considerations.

By far the most important source of raw material is tire scrap. The supply is plentiful and well distributed so that it is relatively easy to collect. The quality of rubber in tires is high, giving an unusually high percentage of rubber hydrocarbon at low cost. The whole tire creates problems due to the tire-cord fiber contained in the carcass portion. This fiber has to be removed either by mechanical means or by chemical methods such as those used in the digester process. In 1972 there were 20 establishments employing 900 persons that shipped products valued at $23 million.(1)

Manufacturing Processes--

Reclaimed rubber is the product resulting from the treatment of ground scrap tires, tubes, and miscellaneous waste rubber articles with heat and chemical agents. Substantial devulcanization or regeneration of the rubber compound to a plastic state is effected, thus permitting the product to be reprocessed, compounded, and revulcanized. The term "devulcanization" which is frequently associated with reclaiming is a misnomer. Devulcanization means breaking the chemical bonds at crosslinking sites. Actually, all the commercial reclaiming processes employed are based on depolymerization of the rubbers. This depolymerization can occur either by promoting thermal scission or breaking of the polymer chain by oxidation at points other than at crosslinking sites. Some scission of the existing crosslinks may also occur.

Three basic techniques are used at existing plants to produce reclaimed rubber: the digester process, the pan process, or the mechanical process. A generalized material flow diagram for the three processes is shown in Figure 38.

Waste Streams--

Wastewater results from the wet digester reclaim processes and air emission results from the various grinding processes, while solid waste is generated from the processes that separate the rubber from the fiber and metal.

Rubber Footwear

This industry consists of companies that manufacture all rubber and plastics footwear, waterproof fabric upper footwear, and other fabric upper footwear having rubber or plastic soles vulcanized to the uppers. This report covers plants that make products of PVC as well as rubber.

This industry shipped products valued at $600 million and 107 establishments employed 31,500 persons in 1972.(1)

Manufacturing Processes--

The process description presented below pertains to canvas shoe production, which utilizes all the major processing technologies commonly found in the manufacture of general fabricated products. A schematic flow diagram for a typical canvas shoe production facility is shown in Figure 39.

The various rubber stocks consumed in a canvas shoe plant are compounded in Banbury mixers or compounding roll mills and then sheeted out. The sheeted rubber is dipped in an anti-tack solution to prevent sticking during storage.

The canvas shoe is built from four major components: soles, canvas uppers, boxing, and inner soles. These components are made separately by varying operations before being brought together in the fabrication operation.

The soles are generally molded by injection, compression, or transfer molding techniques. (All molding processes can produce oil spills and leaks; however, compression and transfer molding equipment generally produce more oil spillage than the injection molding machines.)

The molded soles are deflashed, usually in a buffing machine, before coating with latex adhesive. The latex coating is dried in an oven.

The canvas components for footwear are made from two- or three-ply fabric. The fabric is received at the plant as single sheets. Latex is

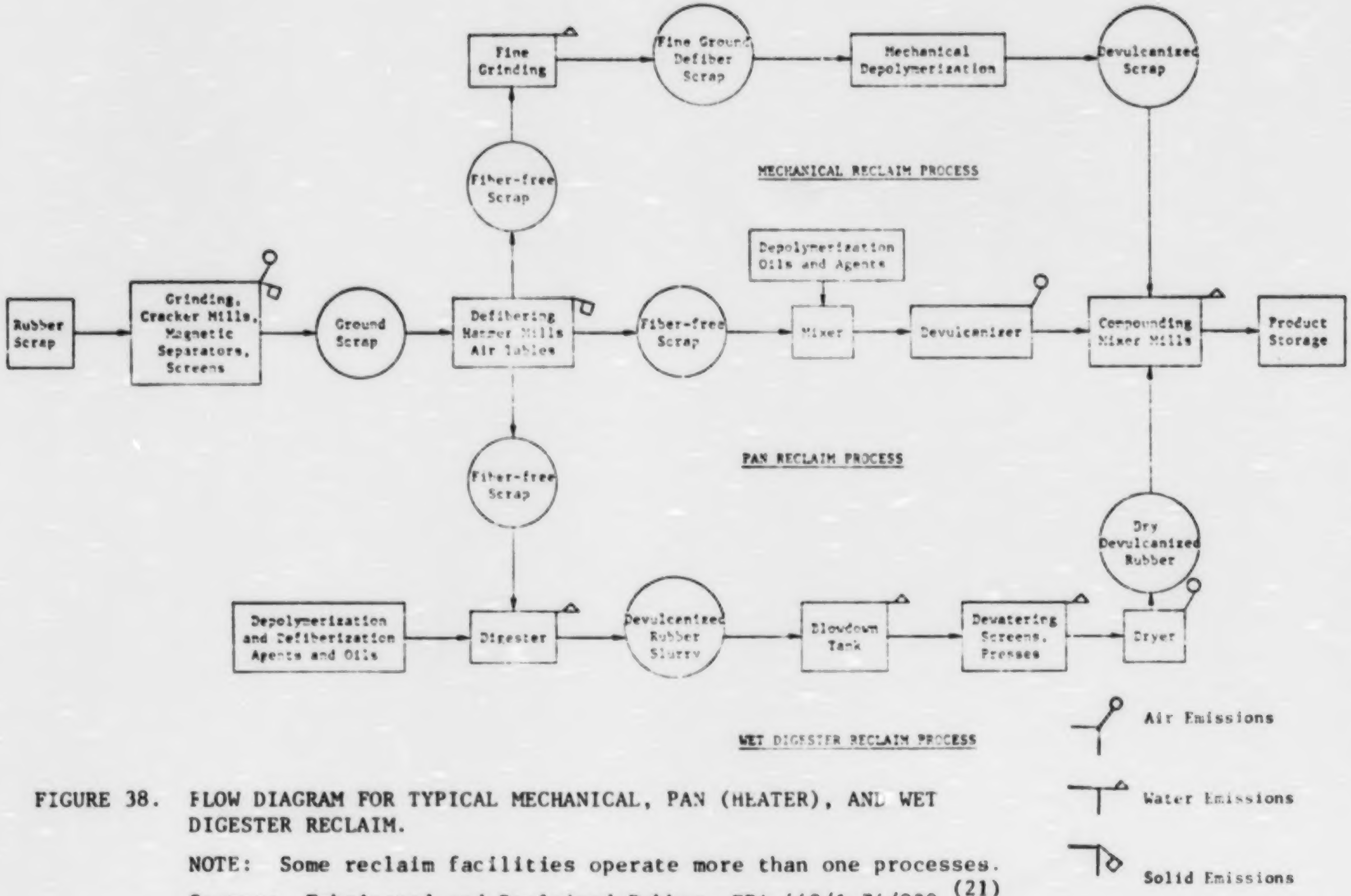

Rubber Scrap
Grinding, Cracker Mills, Magnetic Separators, Screens
Ground Scrap
Defibering Hammer Mills Air Tables
Fiber-free Scrap
Fine Grinding
Fine Ground Defiber Scrap
Mechanical Depolymerization
Devulcanized Scrap
MECHANICAL RECLAIM PROCESS
Fiber-free Scrap
Depolymerization Oils and Agents
Mixer
Devulcanizer
Compounding Mixer Mills
Product Storage
PAN RECLAIM PROCESS
Fiber-free Scrap
Depolymerization and Defiberization Agents and Oils
Digester
Devulcanized Rubber Slurry
Blowdown Tank
Dewatering Screens, Presses
Dryer
Dry Devulcanized Rubber
WET DIGESTER RECLAIM PROCESS
Air Emissions
Water Emissions
Solid Emissions

FIGURE 38. FLOW DIAGRAM FOR TYPICAL MECHANICAL, PAN (HEATER), AND WET DIGESTER RECLAIM.

NOTE: Some reclaim facilities operate more than one processes.

Source: Fabricated and Reclaimed Rubber, EPA 440/1-74/030.(21)

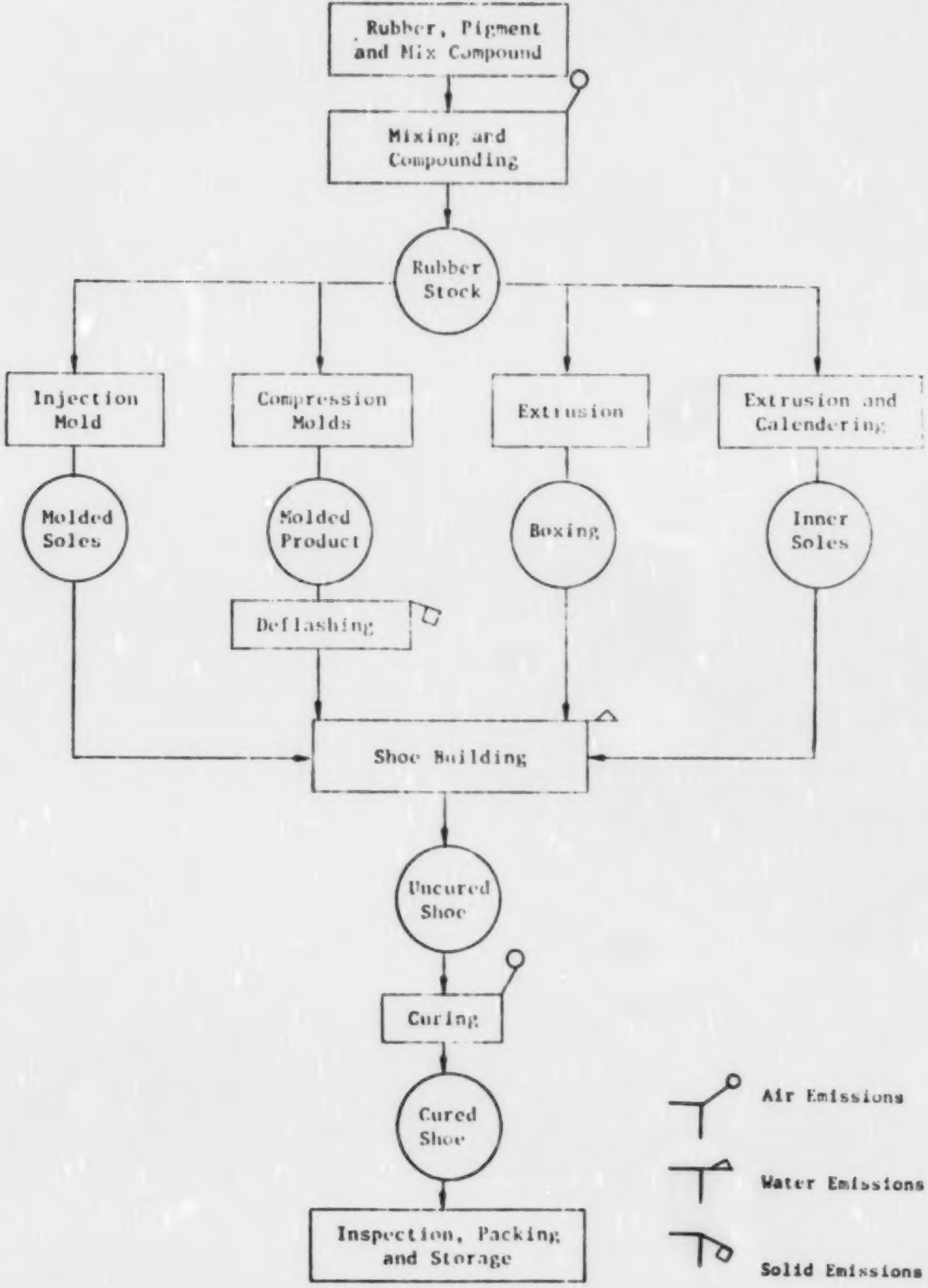

Rubber, Pigment and Mix Compound
Mixing and Compounding
Rubber Stock
Injection Mold
Compression Molds
Extrusion
Extrusion and Calendering
Molded Soles
Molded Product
Boxing
Inner Soles
Deflashing
Shoe Building
Uncured Shoe
Curing
Cured Shoe
Inspection, Packing and Storage
Air Emissions
Water Emissions
Solid Emissions

FIGURE 39. FLOW DIAGRAM FOR THE PRODUCTION OF TYPICAL CANVAS FOOTWEAR ITEM.
Source: Fabricated and Reclaimed Rubber, EPA 440/1-74/030.(21)

applied to the plies, which are pulled together and passed over a heated drum. The sheets are stacked and the multilayer canvas is stamped to shape. The different canvas components making up the shoe uppers are stitched together on sewing machines.

Waste Streams--

Latex is used in several applications as an adhesive. Spills, leaks, and cleanout wastewaters, laden with uncoagulated latex solids, are frequently produced. At the end of the curing cycle the ammonia/air mixture is vented to the atmosphere. Air-pollution control devices are used and no air-pollution problems or requirements appear to be associated with this practice. Solid wastes are generated from the buffing machines.

Miscellaneous Plastics Products

This industry includes establishments primarily engaged in molding primary plastics for the trade, and fabricating miscellaneous finished plastics products. Establishments primarily engaged in manufacturing fabricated plastics products or plastics film, sheet, rod, nontextile monofilaments and regenerated cellulose products, and vulcanized fiber are classified in this industry, whether resins are purchased or produced in the same plant. Establishments primarily engaged in compounding purchased resins are also classified in this industry.

Miscellaneous plastics products were produced by 7,698 plants, in 1972, averaging 45 workers each.(1) Most of these plants (57 percent) employ fewer than 20 workers. This industry shipped products valued at $10.7 billion. A wide diversity of products are manufactured from plastics.

Manufacturing Processes--

Thermoplastic and thermosetting resins are the major raw materials with the principal manufacturing operations being physical property modification, molding and forming, assembly operations, and material coating.

In general, plastics products are made by forcing the compounded raw material to conform to a mold shape, usually by the application of heat and pressure, and then causing the material to solidify to the mold configuration by cooling or curing. Additional work may be done on the molded part such as machining to a finer tolerance or joining of the part to another of a similar or dissimilar nature. After fabrication a functional or decorative coating or other surface alteration may be applied to the part in a finishing operation.

The manufacture of plastic trays is representative of the plastics industry manufacturing processes. A typical operation presently in use in the plastics products industry is shown in Figure 40. The raw material, usually polyethylene, polypropylene, or polystyrene, is received in a standard precompounded form from a volume supplier. The manufacturer usually has a wide choice of standard formulations available to meet his particular functional and esthetic requirements. The resin as received may be dried in a

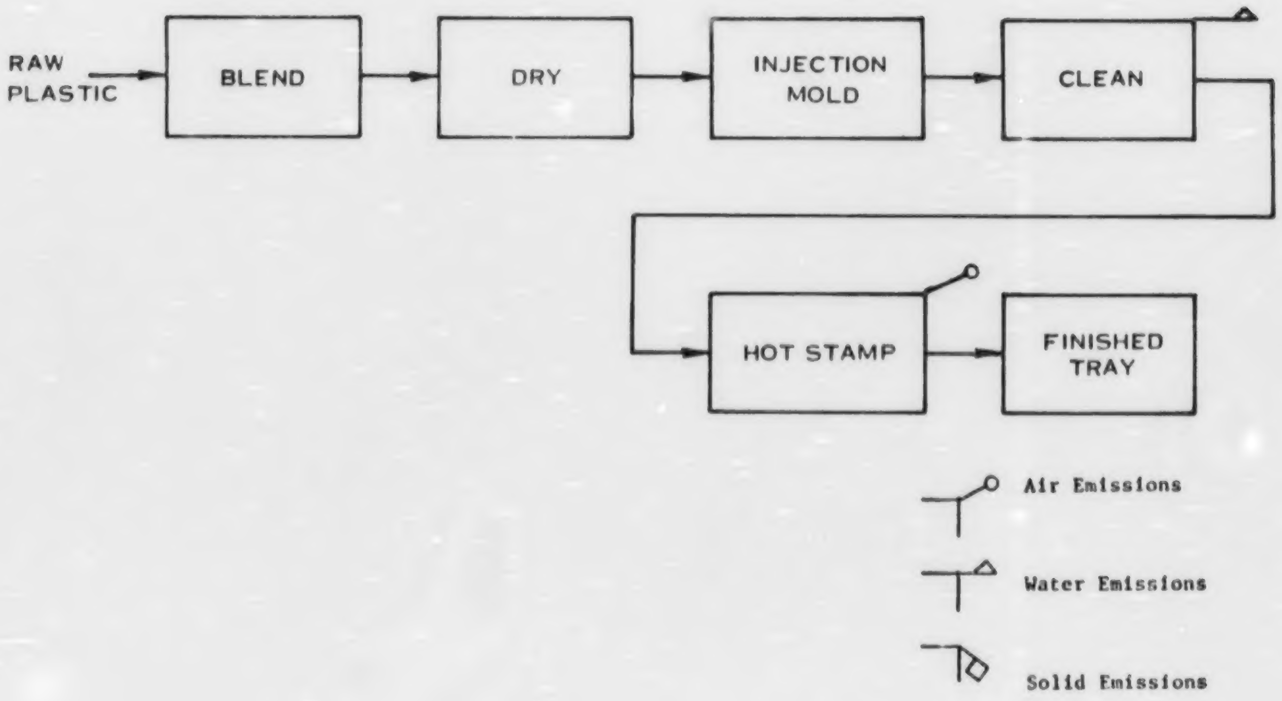

RAW PLASTIC
BLEND
DRY
INJECTION MOLD
CLEAN
HOT STAMP
FINISHED TRAY
Air Emissions
Water Emissions
Solid Emissions

FIGURE 40. PLASTIC TRAY MANUFACTURING.

Source: Machinery and mechanical products manufacturing.(22)

circulating air oven depending upon its hygroscopic properties and the ambient relative humidity.

The raw dried plastic, usually in the form of pellets, is processed by injection molding. Injection molding is a thermoplastic process in which a quantity or "shot" of material in plasticated form is injected into a closed, cooled mold cavity and allowed to harden to the shape of the mold. The part is removed from the mold and then trimmed of excess material. The use of a "paintable" mold-release agent negates the need for any further cleaning operation. The tray is now ready for finishing, which consists of applying a decorative design by hot stamping. Hot stamping is a process in which a heated die is applied to a "color foil" which is in intimate contact with the tray. The die configuration is thereby transferred to the tray as a colored pattern.

Waste Streams--

Process water may be used for the following purposes:

1. Direct contact cooling as in the extrusion process
2. Direct contact heating as in the preexpansion and compression molding of polystyrene foam
3. Washing of oils or water-soluble heating/cooling/ lubricating fluids from a plastic part if such were used during a machining, annealing, or molding process (mold release agents)
4. Removal of dust or paint mist generated in a grinding or spray painting operation
5. Rinsing of plastic parts following an electroplating process
6. Washing of processing equipment contaminated in any of the above processes or in an otherwise clean process such as slush molding.

Solid waste is generated when parts are machined or trimmed. Pollutants emitted to the atmosphere from plastic manufacturing plants include particulates and hydrocarbons. The particulate emissions are resin powders, dust and solid additives. Hydrocarbons consist of blowing agents, monomers, dimers, solvents and additives.

Significant air waste streams can be identified from the unit fabrication methods employed by this segment of the plastics industry. It is known, for example, that the resin-supplying industry has adjusted the rate of free vinyl chloride monomer in PVC to permit safe handling. However, specific problems may exist which would require additional studies to assess their importance. Examples of these specific "potential" problems might be the nitrile blowing agents used in some foam manufacture and the isocyanates used in some blow molding and spray application of urethane. In-depth studies should concentrate on specific materials such as, for example, styrene and acrylonitrile. Both of these materials give off sufficient odor during processing to attest to their volatility. However, it is assumed that styrene is held to acceptable concentrations and no problems exist with acrylonitrile. Both of these suppositions bear further investigation.

LEATHER GOODS

The leather goods industry fabricates many consumer products from leather and other materials. The major types of products include shoes, handbags, purses, wallets, gloves, and luggage.

Many of the products are no longer strictly the province of leather. Many other materials are now used in conjunction with leather or in place of leather. However, these other materials are used by the same establishments that manufacture leather goods, and products including the other materials must be considered as part of the output of the leather goods industry.

There were 2,684 establishments in 1972 primarily engaged in the production of leather goods and related products. They employed 944,000 people, purchased materials valued at $1.953 billion, and shipped products valued at $4.71 billion.(1)

Virtually all of the leather goods industry is embraced within the segments that produce shoes, personal leather goods, and luggage.

Personal Leather Goods

Personal leather goods include women's handbags, purses, and pocketbooks, leather gloves and mittens, billfolds, card cases, glasses cases, cigar cases, cigarette cases, key cases, jewelry cases, tobacco pouches, and other personal items.

There were 794 establishments in 1972 primarily engaged in fabricating such personal items. They employed 39,000 people; purchased leather valued at $70 million, fabrics and other sheet goods valued at $87 million, and other materials worth $115 million; and shipped products valued at $705 million.(1) It is noteworthy that the value of non-leather sheet goods exceeded by nearly 25 percent the value of leather purchased.

Luggage

Luggage includes suitcases, traveling bags, trunks, valises, shoe kits, satchels, sample cases, briefcases and attaché cases, cases for musical instruments, camera bags and cases, and hat boxes (except paper and paperboard).

There were 277 establishments in 1972 primarily engaged in manufacturing such products. They employed 17,000 people; spent $5 million for leather, $39 million for fabrics and other sheet goods, and $102 million for other materials; and shipped products valued at $365 million.(1) These statistics show clearly that leather is no longer a very important material of construction in the luggage segment of the leather goods industry. Furthermore, the value of hardware and other non-sheet materials purchased far exceeds the value of all sheet materials purchased as linings, walls, and pockets for luggage.

Shoes

The manufacture of shoes includes the cutting of boot and shoe stock and the production of shoes, boots, house slippers, and other footwear (except rubber) for men, women, and shildren. In 1972, there were 1,165 U.S. establishments primarily engaged in fabricating shoes of leather and other materials. They employed 881,000 people; spent $600 million for leather, $274 million for other sheet goods, and $594 million for other materials; and shipped products valued at $3.479 billion.(1)

Manufacturing Processes(23)--

The manufacturing processes for shoes are more complex than are those for other leather goods. Because of the dominant position of shoe manufacturing in the leather goods industry and the complexity of the shoemaking process, no other processes will be discussed.

The basic operations in shoe manufacturing are cutting, forming, and fastening, but these are broken down into several suboperations. Furthermore, due to the advent of many new materials and new machinery, there are many variations in the shoe-manufacturing process.

Figure 41 shows a generalized process for the manufacturing of shoes. This process should be approximately correct for shoes of any conventional manufacture, although it does not apply to any type of molded footwear. Different manufacturers may combine these operations in various ways.

The shoe industry has descriptive names for process operations, or the rooms in which they occur, that may not be readily understood by those outside the industry. The activities that occur in these various operations will be discussed briefly in the following paragraphs.

Cutting Room--The parts for the shoe upper are cut here with dies. In the case of leather uppers, the dies must be so placed on the leather as to provide appropriate characteristics for the different parts of the shoe and care must be taken to avoid color mismatches. A great deal of money can be lost through careless or unskilled cutting.

In addition to leather, upper parts of fabric, vinyl, or other materials are cut here, as well as liner materials.

Stitching Room--In the stitching (fitting) room, the edges of the die-cut leather uppers are skived (tapered) to provide a bevel for good fit. Some areas of the uppers may be split to provide thinner leather in some parts of the shoe. The parts are appropriately sewed together and the seams are rubbed or taped to make them smooth. Reinforcing materials may be added here, and an inner lining may be cemented on. Top edges are folded and

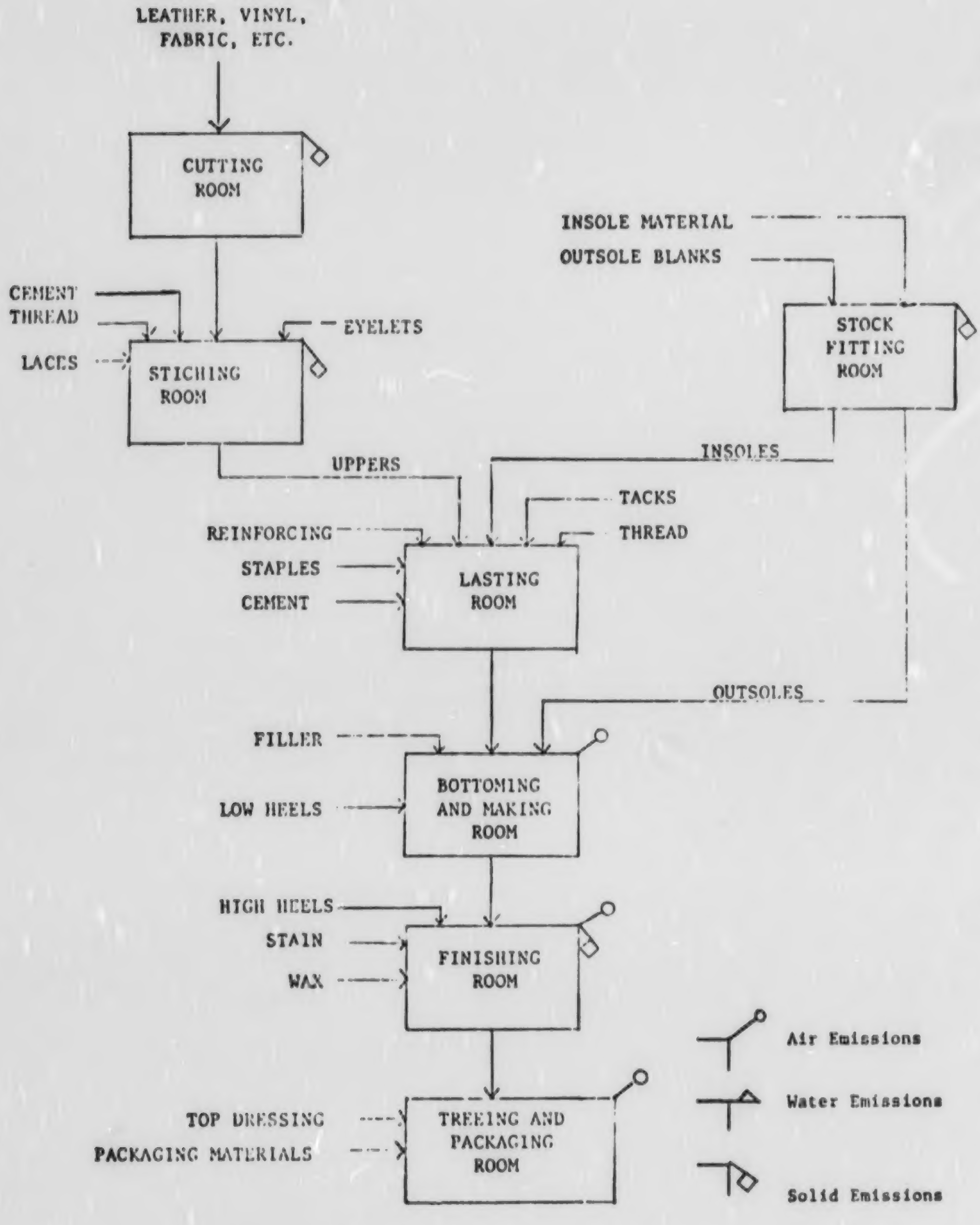

LEATHER, VINYL, FABRIC, ETC.
CUTTING ROOM
CEMENT
THREAD
LACES
EYELETS
STICHING ROOM
INSOLE MATERIAL
OUTSOLE BLANKS
STOCK FITTING ROOM
UPPERS
INSOLES
TACKS
THREAD
REINFORCING
STAPLES
CEMENT
LASTING ROOM
OUTSOLES
FILLER
LOW HEELS
BOTTOMING AND MAKING ROOM
HIGH HEELS
STAIN
WAX
FINISHING ROOM
TOP DRESSING
PACKAGING MATERIALS
TREEING AND PACKAGING ROOM
Air Emissions
Water Emissions
Solid Emissions

FIGURE 41. GENERALIZED PROCESS FOR MANUFACTURING SHOES.
Source: Practical leather technology.(23)

cemented or stitched, eyelets are placed, and laces are put in place.

Stock Fitting Room--In this area, insoles are die-cut from appropriate materials and outsole blanks are reduced in thickness near the edges or otherwise prepared for use, depending on the type of construction to be used.

Lasting Room--The upper, insole, and reinforcing parts of the shoe are brought together in the lasting room. Operations vary somewhat, depending on the type of construction being used. In a typical operation, the insole is first tacked to the last, then the upper is fitted to the last and tacked on. The toe is pulled over with a machine, then the component parts are fastened together by stitching, cementing, or stapling, depending on the particular construction.

Bottoming Room--The outsole is attached to the shoe in the bottoming and making room. In some types of construction, a filler is placed between the insole and the outsole before final attachment. The sole may be attached by sewing or cementing, perhaps with some use of tacks or staples as well. Low heels are attached while the shoe is still on the last.

Two recent developments that help reduce manufacturing costs are the direct-molded sole and the injection-molded sole. In the direct-molding operation, the preformed upper and insole assembly is placed on top of the precut sole in a mold. Heat and pressure applied to the mold force the sole into the desired shape and vulcanize the sole in a firm bond with the upper. In the injection-molding operation, the preformed upper insole assembly is placed in a mold and the molten outsole material is forced into the lower part of the mold, forming and bonding the sole in place.

Finishing Room--The attached outsoles are trimmed and smoothed in the finishing room, and the edges are stained and waxed. If the shoe is to have a high heel, it is removed from the last before attaching the heel with nails driven from inside the shoe into the heel.

Treeing and Packaging Room--The completed shoes are cleaned and may be given a top dressing. After buffing and inspection, they are packaged and stored for inventory and shipment.

Waste Streams--

The activities that produce waste streams will be discussed briefly in the following paragraphs.

Cutting Room--Considerable cutting scrap arises from this operation. To the extent that it is not reusable, it makes a significant contribution to solid waste.

Stitching Room--Material removed in skiving, splitting, and the placing of eyelets constitutes a modest solid waste.

Stockfitting Room--Significant solid waste arises from these cutting and trimming operations.

Lasting Room--There should be no significant waste stream from lasting other than thread ends and an occasional bent tack or staple.

Bottoming Room--There should be no significant waste stream from conventional bottoming and making operations. Some air pollutants are emitted when soles are direct-molded or injection-molded.

Finishing Room--Some solid waste is generated in trimming and burnishing the sole edges. Solvents used in the staining and waxing formulations create modest air pollution.

Teeing and Packaging Room--Solvents used in top dressing formulation cause modest air pollution.

FLEXIBLE ROOFING, FLOORING, AND PAVING PRODUCTS

This industry includes establishments that manufacture asphalt materials for roofing, asphalt and vinyl-asbestos floor coverings, and asphalt and tar paving materials. In 1972 there were approximately 1,240 such plants that employed about 35,400 people and shipped products valued at $2.142 billion.

Asphalt Paving Mixtures and Blocks

This industry includes plants primarily engaged in the manufacture of asphalt and tar paving mixtures and paving blocks made of asphalt, creosoted wood, and various compositions of tar and other materials. Shipments of paving mixtures and blocks in 1972 represented 93 percent of the industry total product shipment. The census of manufactures reported 586 companies and 964 plants in 1972 producing paving mixture and blocks in the United States.(1) They employed 13,900 people and shipped products valued at $923 million.

In addition, there are approximately 4,800 asphalt paving plants in the United States that use paving products.(15) An estimated 1,200 plants are mobile plants operated by highway contractors.(16) To the extent that the paving plants prepare their own paving products, they would have waste streams comparable to those of the paving mixtures and block industry. These paving contractors also have waste streams associated with use of the paving products. However, they are not included in this study of compounding and fabricating industries.

Manufacturing Processes--

Asphaltic concrete is the combined product of sand or gravel with asphalt, as shown in Figure 42. The sand or gravel is heated and dried in a rotary drier. The dried sand or gravel is transported to a mixing hopper where a weighed amount of asphalt is introduced.(17)

Waste Streams--

Asphalt concrete has been recognized as a major source of particulate

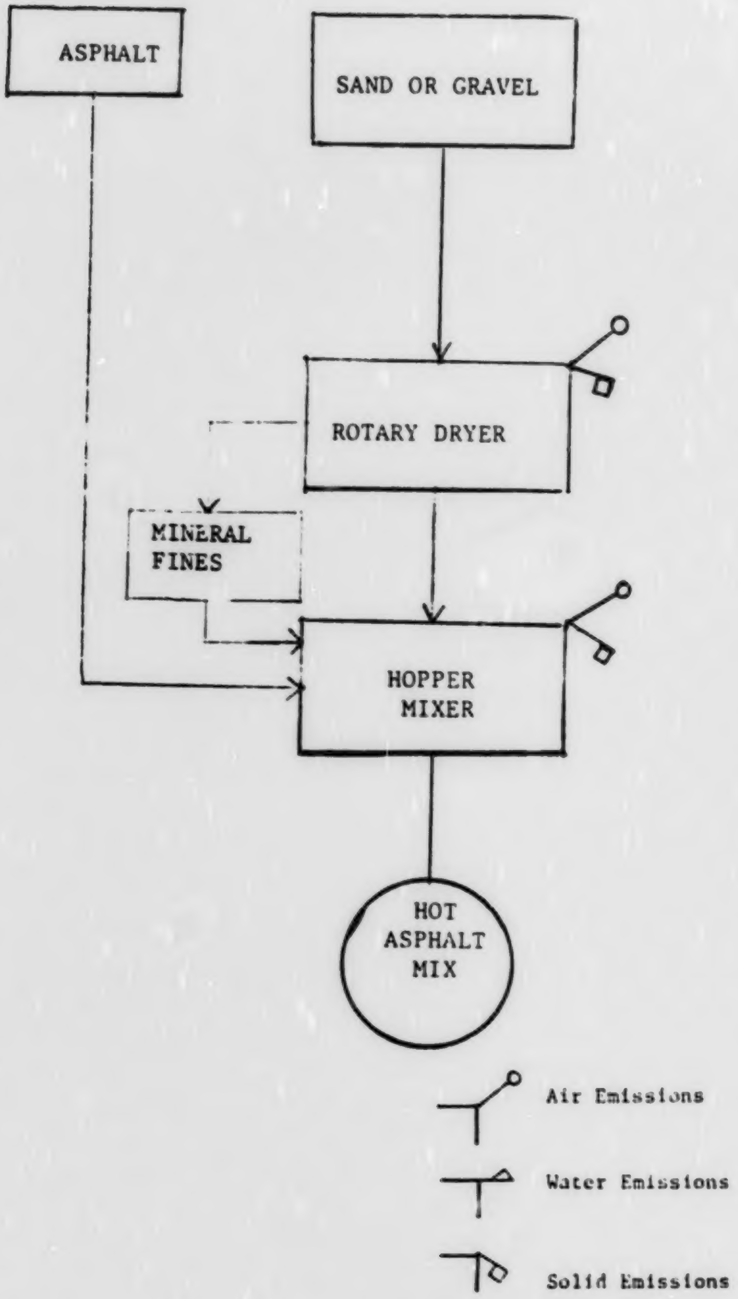

ASPHALT
SAND OR GRAVEL
ROTARY DRYER
MINERAL FINES
HOPPER MIXER
HOT ASPHALT MIX
Air Emissions
Water Emissions
Solid Emissions

FIGURE 42. MANUFACTURING PROCESS FOR ASPHALTIC CONCRETE.

emissions in the United States.(17) Fabric filter and medium energy scrubbers preceded by a cyclone are used to collect dust from the dryer. The dry collection system is the most widely used system in the industry today. Mineral fines collected in the dryer are used in the hopper mixer. Emissions also occur from the asphalt storage tank. The wet system is costly to install and maintain. The resultant slurry is usually discharged to an open pit, where settling occurs and the clear water is recycled. Fugitive dust is also an environmental problem in this industry.

Asphalt Felts and Coatings

This industry comprises establishments primarily engaged in the manufacture of asphalt-saturated felts in roll or shingle form, either smooth or faced with grit, and in manufacturing roofing cements and coatings. In 1972 there were 225 asphalt roofing plants in the United States.(1) The shipments of this industry were valued at $869.5 million in 1972.

Manufacturing Processes--

The raw material consists of felt, asphalt, sand, mica, granules, and talc.

Asphalt roofing and shingles are manufactured on high-speed continuously operating machines. Some types are produced at a rate as high as 500 feet per minute.

The process consists of saturating the felt, coating the surfaces with asphalt, coating with pulverized or granular minerals, cooling, cutting, and packaging. (Figure 43).

Saturation of Felt--A roll of felt is installed on a felt reel, then is subjected to a hot saturating process. The usual saturation temperature is between 232 and 260 C. The function of the asphalt saturant is to fill the voids in the felt, help bind the felt fibers, and "prime" the felt to assure good coating adhesion and improve the weather resistance of the felt without damaging the weather-resistant coating.

Coater--After saturation, the sheet is carried to the coater where the coating asphalt is applied to both the top and the bottom surfaces. The temperature of the coating asphalt is usually in the range of 177-204 C.

Mineral Surfacing Application--When smooth-roll roofing is being made, talc or mica or another parting agent is applied to the two sides of the roofing sheet and pressed into the coating by the press rolls. When mineral surface is being prepared, colored granules are added from a hopper and spread thickly on one side, and backing material on the other side.

Finish or Cooling Looper--The function of the looper is to cool the sheet down to a point where it can be cut and packed without damage to the material. The cooling of the sheet is accomplished by either splashing water or by spraying water on the hot sheet.

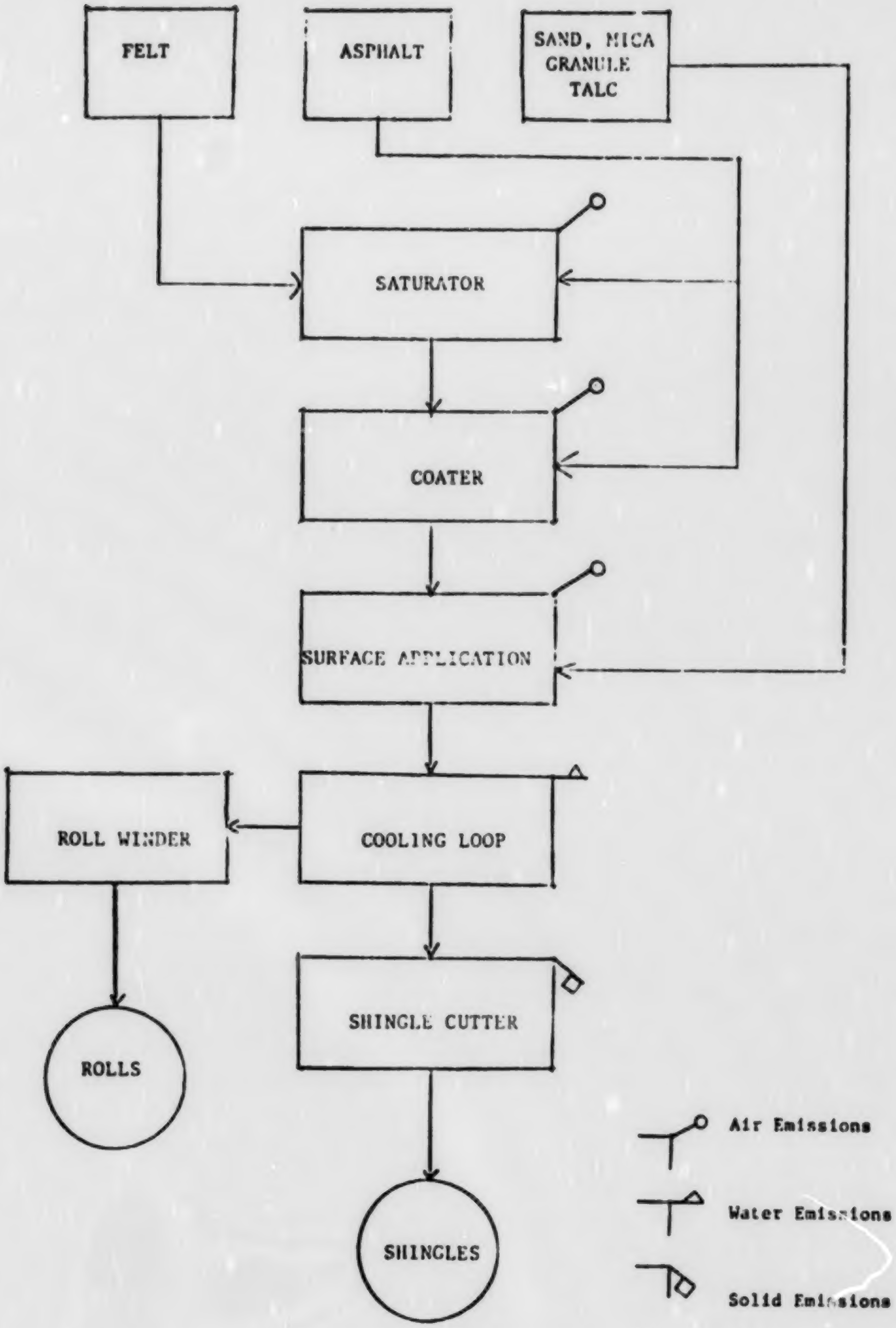

FELT
ASPHALT
SAND, MICA
GRANULE
TALC
SATURATOR
COATER
SURFACE APPLICATION
ROLL WINDER
COOLING LOOP
SHINGLE CUTTER
ROLLS
SHINGLES
Air Emissions
Water Emissions
Solid Emissions

FIGURE 43. FLOW DIAGRAM OF MANUFACTURING ASPHALT FELT ROLLS AND SHINGLES.

Waste Streams--

Low-boiling-point hydrocarbon oils in the form of dense white air emissions varying in opacity from 50 to 100 percent are generated from the saturation of felt; dust is emitted from the mineral application process. The wastewater is generally pollution-free except for suspended particulates of coatings granules washed off the felts.

Hard-Surface Floor Covering

This industry includes establishments that manufacture floor covering such as vinyl-asbestos tile, vinyl sheet, and asphalted felt-base coverings (linoleum). However, linoleum is slowly being phased out and being replaced by newer vinyl floor covering. Most floor tile manufactured today uses a vinyl resin, although some asphalt tile is still being produced. The value of shipments in 1972 was $153.5 million for vinyl-asbestos floor tile and $25 million for asphalt floor tile.(1)

Manufacturing Processes(18)--

The tile-manufacturing process, shown in Figure 44, involves several steps: ingredient weighing, mixing, heating, decoration, calendering, cooling, waxing, stamping, inspecting, and packaging. The ingredients are weighed and mixed dry. Liquid constituents, if required, are then added and thoroughly blended into the batch. After mixing, the batch is heated to about 150 C and fed into a mill where it is joined with the remainder of a previous batch for continuous processing through the rest of the manufacturing operation.

The mill consists of a series of hot rollers that squeeze the mass of raw tile material down to the desired thickness. During the milling operation, surface decoration in the form of small colored chips of tile (mottle) are sprinkled onto the surface of the raw tile sheet and pressed in to become a part of the sheet. Some tile has a surface decoration embossed and linked into the tile surface during the rolling operation. This may be done before or after cooling. After milling, the tile passes through calenders until it reaches the required thickness and is ready for cooling. Tile cooling is accomplished in many ways and a given tile plant may use one of several methods. Water-contact cooling in which the file passes through a water bath or is sprayed with water is used by some plants. Others use non-contact cooling in which the rollers are filled with water. In some plants, the sheet of tile passes through a refrigeration unit where cold air is blown onto the tile surface. After cooling, the tile is waxed, stamped into squares, inspected, and packaged. Trimmings and rejected tile squares are chopped up and reused.

Waste Streams--

Direct contact cooling water from the cooling baths or sprays becomes contaminanted. Air emissions result from the mixing of the raw ingredients.

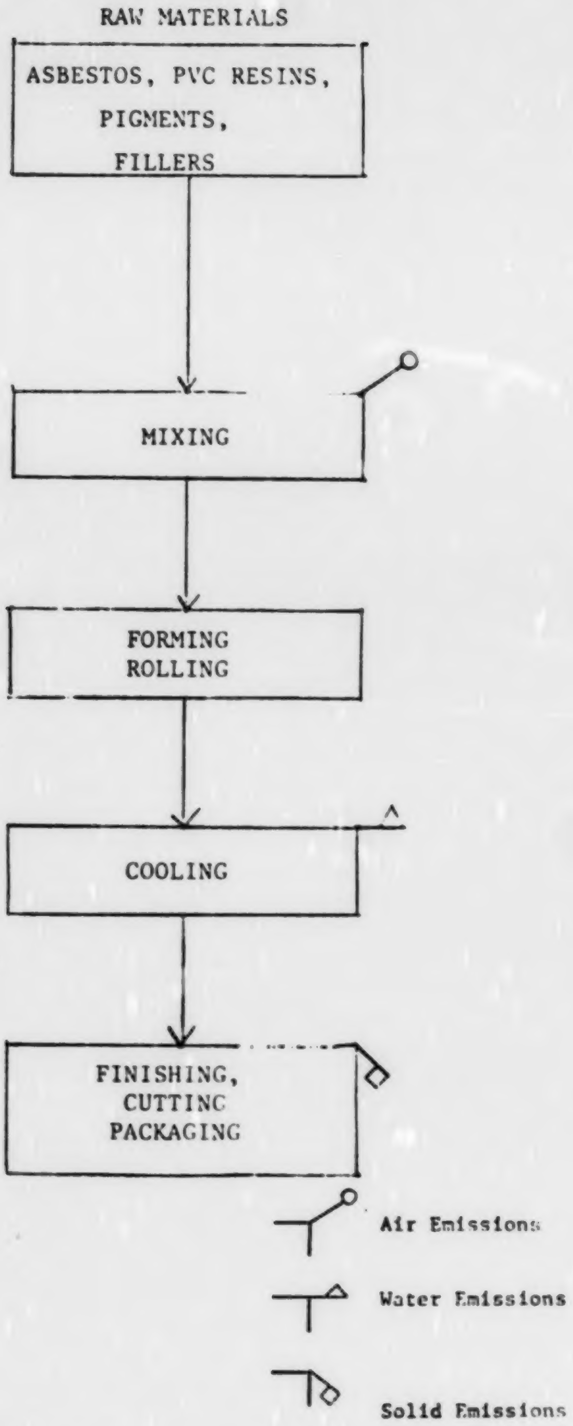

RAW MATERIALS
ASBESTOS, PVC RESINS,
PIGMENTS,
FILLERS
MIXING
FORMING
ROLLING
COOLING
FINISHING,
CUTTING
PACKAGING
Air Emissions
Water Emissions
Solid Emissions

FIGURE 44. ASBESTOS FLOOR TILE MANUFACTURING.

INORGANIC MINERAL PRODUCTS

This large industry consists of establishments primarily engaged in manufacturing finished products from clay, glass, concrete and other inorganic minerals. The segments of industry engaged in mining operations or in producing the raw materials used in the finished products are not included.

Mirrors Made from Purchased Glass

Mirrors manufactured from purchased glass are included in this industry. Primary products are mirrors either framed, unframed, truck, or automobile.

Numerous manufacturing plants in the United States produce one or more of the above products. These plants are distributed throughout the states.(24)

In 1972, shipments of mirrors from purchased glass amounted to $254.5 million. Framed, unframed, and automobile mirrors accounted for 33, 36, and 31 percent, respectively, of the value of shipments.(1)

Manufacturing Processes--

The process for manufacturing mirrors from purchased glass consists of a series of sizing and finishing operations, as shown in Figure 45a. Glassware is usually received at manufacturing facilities in bulk and is scribed and broken or cut into desired sizes. Although much of this glass is used as-received, some of the glass is shaped. For store-security mirrors, for example, the glass is made convex by heat treatment. After shaping, this glass undergoes several finishing operations including polishing and heat-tempering.

Mirrors undergo a coating operation before final finishing and assembly. After rinsing the mirror surface with stannous chloride, the surface is coated with silver nitrate. Coatings are bonded to the glass by firing coated glassware at elevated temperatures.(25) After firing, mirrors are cooled and undergo a series of final finishing operations. These operations include polishing, etching, and engraving. About 33 percent of these mirrors are assembled into frames, while 36 percent are sold unframed. The remainder are used for automobile mirrors.

Waste Streams--

Three types of waste streams are involved in the manufacture of mirrors from purchased glass. These are air, water, and solid. This industry is generally not considered a major polluter and, as a result, little attempt has been made to reduce emissions. Air emissions include glass particulates. Other air emissions are dependent upon the type of fuel used for curing coatings. Water emissions include glass particulates and silver nitrate. Solid-waste stream emissions consist almost exclusively of glass.

Glassware-finishing operations are sources of particulate emissions into air-waste streams. Grinding, polishing, and engraving of glass surfaces are

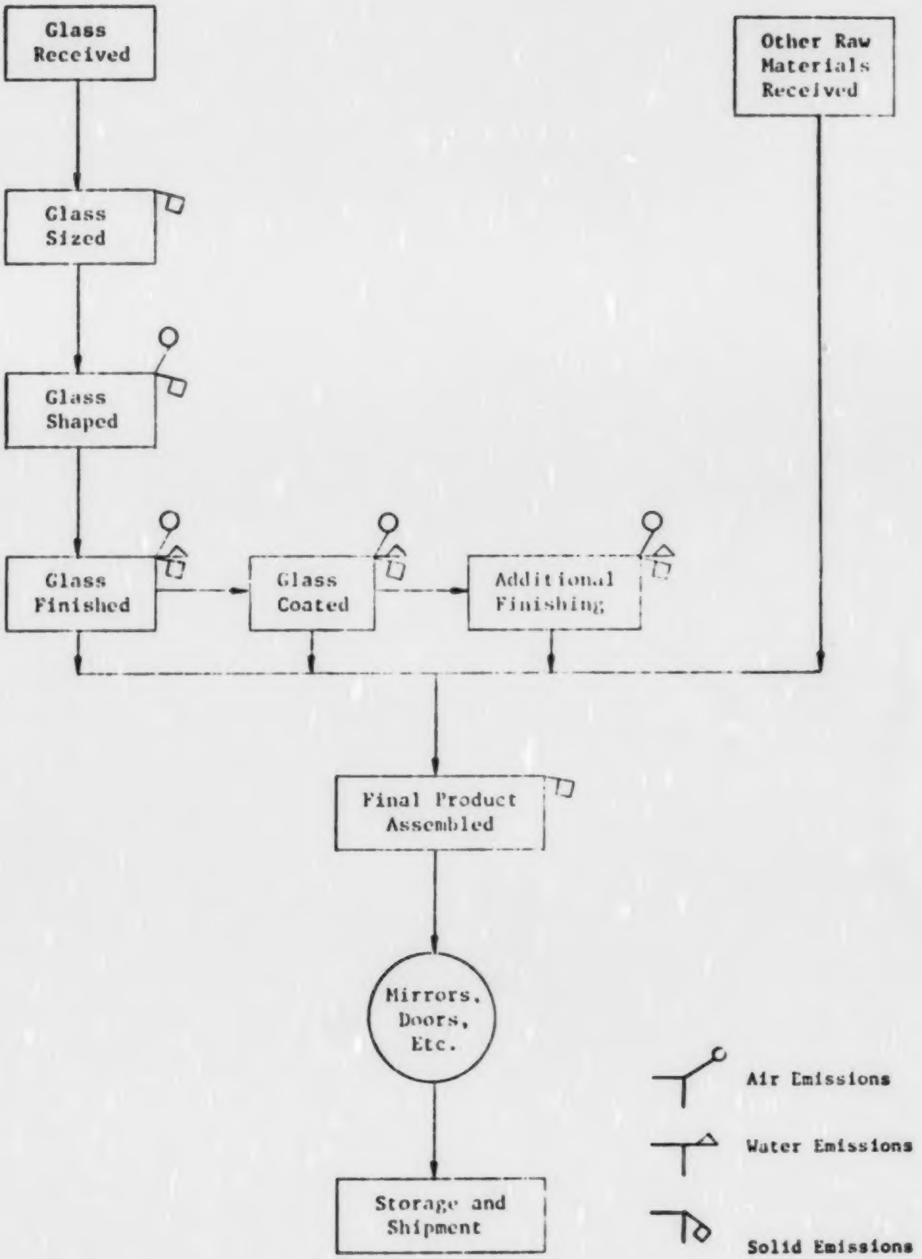

Glass Received
Glass Sized
Glass Shaped
Glass Finished
Glass Coated
Additional Finishing
Other Raw Materials Received
Final Product Assembled
Mirrors, Doors, Etc.
Storage and Shipment
Air Emissions
Water Emissions
Solid Emissions

FIGURE 45a. PROCESS FLOW DIAGRAM FOR THE MIRROR, DOOR, AND WINDOW (MADE FROM PURCHASED GLASS) INDUSTRY.

usually hooded operations and the emissions generally are collected on fabric filters. Thus, few of these particulates are discharged into the atmosphere.

The firing of surface coatings also results in airborne emissions. These emissions are generally dependent upon the type of fuel used. Natural gas, for example, could result in NO_x (NO or NO_2), particulates, CO, and hydrocarbons. Fuel oils, on the other hand, could additionally result in SO_x (SO_2 or SO_3) emissions. Electric fuel-fired lehrs are virtually "clean" and should result in little, if any, air emissions.(26)

Coating and finishing operations are both sources of water pollutants. In both cases, water is used for cooling purposes. This water is generally reused numerous times before discharge. Discarded water is generally discharged into a sewer or septic system or into a settling pond. This water generally contains a glasseous sludge and heat, either of which could present a pollution problem.

Other Products Made from Purchased Glass

The manufacture of products from purchased glass is included in this industry. Several of these products are:

Aquariums
Art glass
Artificial flowers, foliage, fruits, and vines
Christmas-tree ornaments
Cut and engraved glassware
Decorated glassware: chipped, engraved, etched, sandblasted, etc.
Doors
Grass, artificial
Marbles
Mosaics
Scientific and technical glassware
Windows.

There are over 200 glass plants producing one or more of the above products. These plants are distributed throughout the United States, with the largest proportion of volume, over 53 percent, in New Jersey, New York, Ohio, and Pennsylvania. New York accounts for almost 25 percent of the plants.(24)

In 1972, shipments of novelties made from purchased glass exceeded $180 million. This amounted to an increase of 27 percent over 1967 value of shipments.(1)

Manufacturing Processes--

The manufacturing process of products from purchased glass consists of a series of sizing and finishing operations, as shown in Figure 45b. Glassware and other raw materials are usually received at manufacturing facilities in bulk. Before the glass is processed, it is sized by cutting and scribing and breaking. Although much of this glass is used as-received, some of the glass is shaped by heat. Artificial flowers, foliage, fruits, and so forth, are

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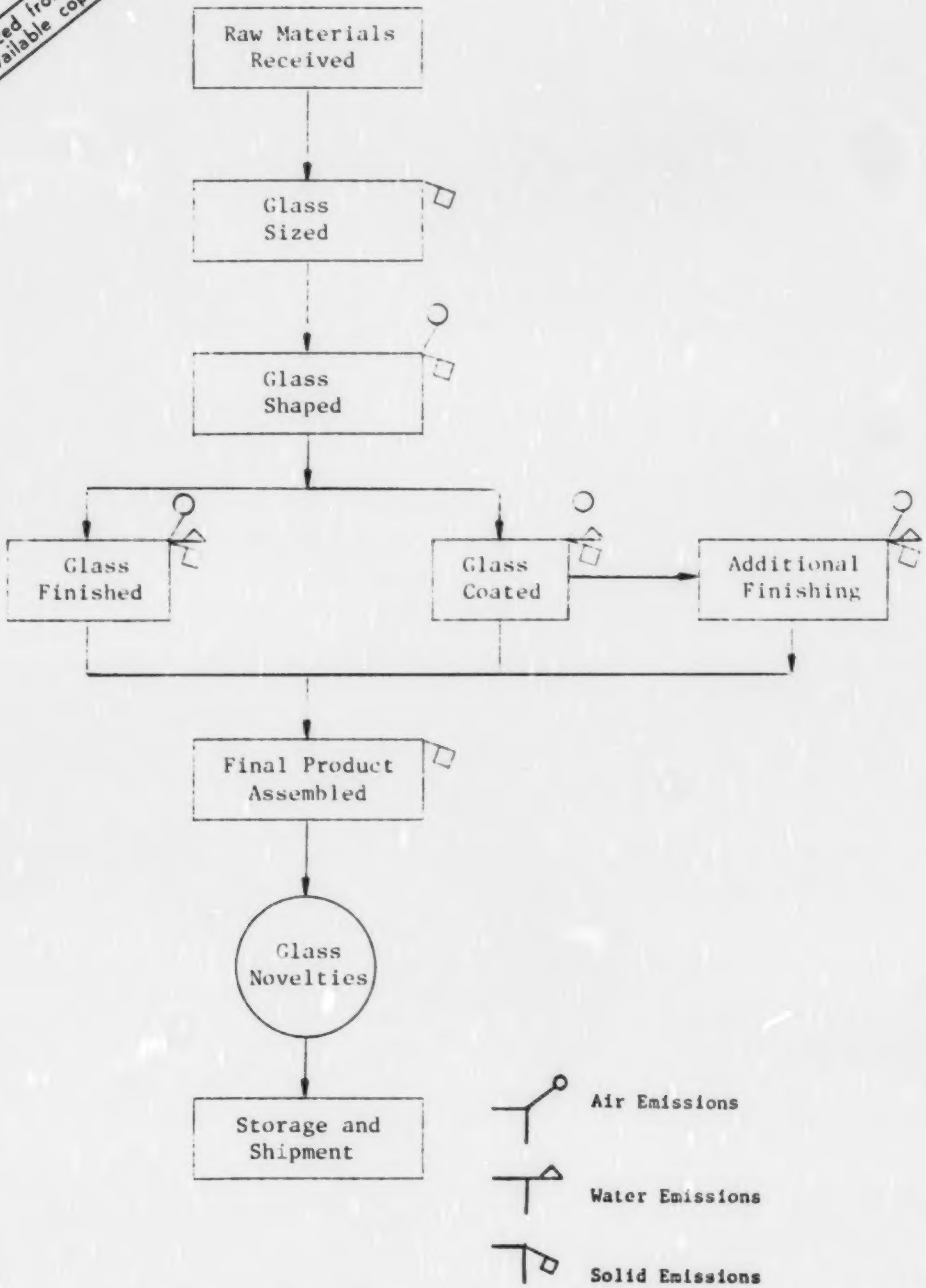
Raw Materials Received
Glass Sized
Glass Shaped
Glass Finished
Glass Coated
Additional Finishing
Final Product Assembled
Glass Novelties
Storage and Shipment
Air Emissions
Water Emissions
Solid Emissions

FIGURE 45b. PROCESS FLOW DIAGRAM FOR PRODUCTS MANUFACTURED FROM PURCHASED GLASS.

heated to the glass melting point and bent to the desired shape. Once the glass is in the desired shape, it undergoes several finishing-type operations. These operations include polishing, heat tempering, etching, and engraving. After finishing, aquariums, art glass, doors, mosaics, and windows are assembled. Christmas-tree ornaments and most scientific and technical glassware, on the other hand, are coated with enamels, decals, or other materials. Enamels and some decals are bonded to the surface by heat. Other decals and decorating materials are stuck to the surface of the ornaments by using a commercial adhesive. These various types of glass products are stored until they can be loaded for shipment.

Waste Streams--

This industry is generally not considered a major polluter and, as a result, little attempt has been made to reduce emissions. Air emissions include glass particulates and other emissions, depending upon the type of fuel used for shaping. Water emissions include glass particulates and heat. Solid-waste stream emissions consist almost exclusively of glass.

Glassware-finishing operations are sources of particulate emissions into air-waste streams. Grinding, polishing, and engraving of glass surfaces are usually hooded operations and the emissions generally are collected on fabric filters. Thus, few of these particulates are discharged into the atmosphere.

During the shaping operation, various types of pollutants can be emitted. These emissions are generally dependent upon the type of fuel used.

Coating and finishing operations are both sources of water pollutants. In both cases, water is used for cooling purposes. This water is generally reused numerous times before discharge. Discarded water is generally discharged into a sewer or septic system or into a settling pond. This water generally contains a glasseous sludge and heat, either of which could present a pollution problem.

Solids are generally emitted from the sizing, shaping, finishing, and assembly operations. These emissions consist of a glasseous solid and are normally returned to the glass plant as cullet. This solid waste is not expected to present a pollution problem.

Concrete Building Block and Brick*

This classification includes concrete and cinder blocks and concrete brick as major products. Minor products include:

Concrete decorative block (split, slump, shadowall)
Precast terrazzo plinth blocks
Sand-lime blocks
Building blocks and bricks made from other material.

---

* Unfired brick only. The common-fired clay brick is included in the refractories industry.

Over 1300 manufacturers operate block and brick plants in the United States. Most plants are located from 50 to 100 miles from active construction areas. Because of the high population density and subsequent large amount of construction, the southeast, northeast, and north-central areas(5) contain approximately 74 percent of these plants.

In 1972, this industry employed over 22,800 people in 1388 establishments and had total shipments of about 94 million blocks and bricks, valued at $856 million.(1) By 1973, the number of people employed had decreased slightly, while the number of blocks and bricks shipped increased to over 98 million.

Manufacturing Processes--

Building blocks and bricks are manufactured from a variety of materials, with the most common manufactured from portland cement concrete. Other materials used include: lava, lightweight concrete, gypsum, granite, cinders, and sand-lime.

Typical steps in block and brick manufacture, along with expected waste streams, are shown in Figure 46. Controlled mixtures of a bonding material (e.g., portland cement), aggregates (e.g., sand, gravel, etc.) and water are batched and mixed at the block and brick plant. After the batch has been blended to the desired consistency, the material is formed and compacted with vibration and pressure in steel molds. These formed blocks and bricks are then discharged from the molds and cured by high-pressures steam, low-pressure steam, or ambient air. Steam curing is essential for high production and volume operations, as well as sand-lime and cinder block manufacture. Only in small operations are products air cured. After curing, blocks and bricks are cubed, strapped, stacked, and stored until they can be loaded for truck shipment.

Waste Streams--

Previous studies(27,28) indicate that this industry is not a major polluter and, as a result, little attempt has been made to reduce emissions. Emissions generally reflect the raw materials used except during curing. Curing-operation emissions reflect the type of fuel used as well as the decomposition of the curing-room shell.

Emissions occur in the air-waste stream during raw materials unloading, batching, mixing, and steam curing; particulates are emitted into the atmosphere. The composition of these particulates generally reflects that of the raw materials. However, emissions from steam curing are dependent upon the type of fuel used.

Molding, racking, and steam curing are sources of water-waste stream emissions. For steam curing, water is used for steam and for boiler cooling. Steam is driven off into the air-waste stream. Cooling water, however, is either reused, recycled, or discarded. Discarded cooling water either enters

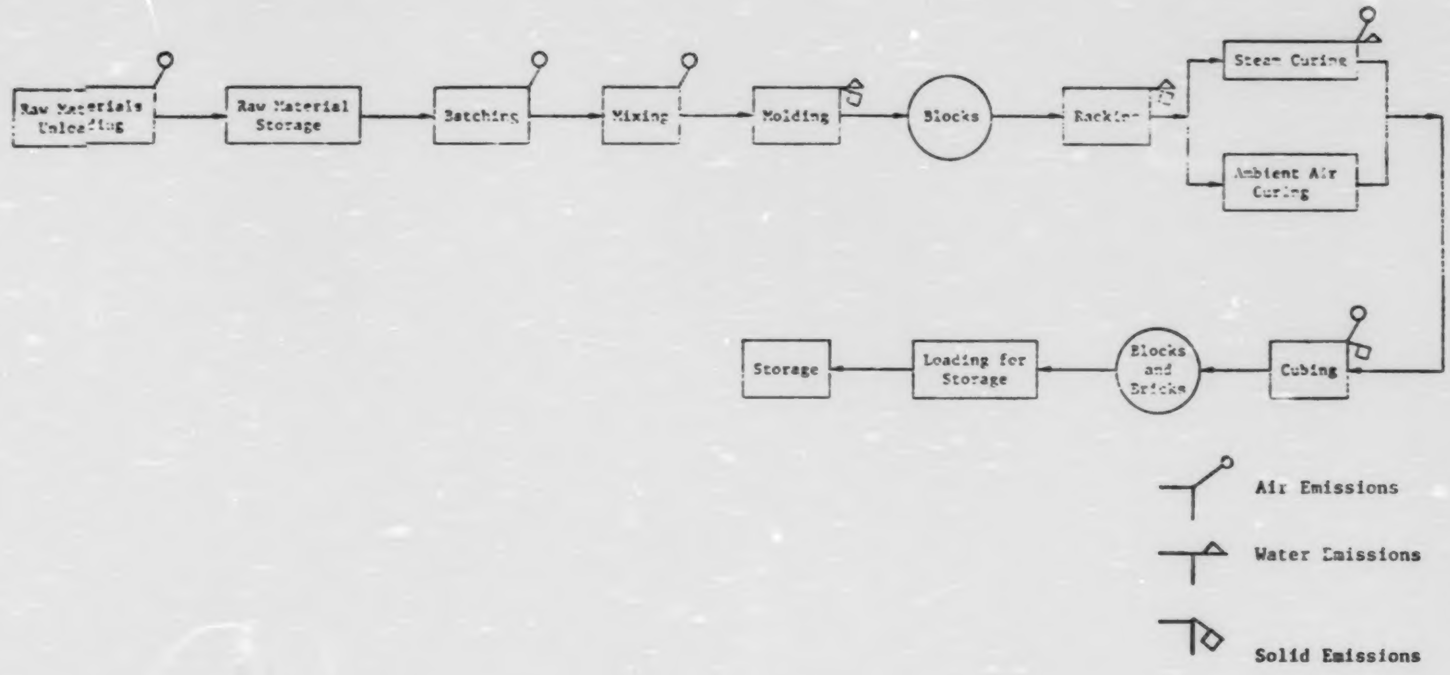
Raw Materials Unloading
Raw Material Storage
Batching
Mixing
Molding
Blocks
Racking
Steam Curing
Ambient Air Curing
Cubing
Blocks and Bricks
Loading for Storage
Storage
Air Emissions
Water Emissions
Solid Emissions

FIGURE 46. PROCESS FLOW DIAGRAM FOR BLOCK AND BRICK MANUFACTURE.

the plant's water-waste stream or is discharged into a pond. The discarded water generally contains suspended particulates and has an elevated temperature.(29)

During molding and racking operations, water is used to rinse the molds and racks. Although this water is often reused, it eventually is discharged into a waterway or settling pond. Particulates and some solids are discharged in this manner.(29)

Solid wastes are usually discharged during the molding, racking, and cubing operations. Most of these emissions from molding and racking are reused, while most solid wastes from cubing are discharged. These solid wastes are composed of broken or "scrap" blocks and bricks and could represent a pollution problem.

Other Concrete Products

The manufacture of concrete products (except block and brick) from a combination of portland cement and aggregate is included in this industry. Major products include ready-mixed concrete, precast-concrete products, and prestressed concrete. Other concrete products include:

Areaways, basement window: concrete
Art marble, concrete
Ashlar, cast stone
Bathtubs, concrete
Battery walls and boxes, concrete

Building materials, concrete: except block and brick
Building stone, artificial: concrete
Burial vaults, concrete
Cast stone, concrete
Catch basin covers, concrete

Ceiling squares, concrete
Central-mixed concrete
Chimney caps, concrete
Church furniture, concrete
Columns, concrete

Concrete, dry mixture
Copings, concrete
Covers, catch basin: concrete
Cribbing, concrete
Crossing slabs, concrete

Door frames, concrete
Drain tile, concrete
Fireplaces, concrete
Fountains, concrete
Garbage boxes, concrete

Grave markers, concrete
Grave vaults, concrete
Grease traps, concrete
Housing components, prefabricated: concrete
Incinerators, concrete

Joists, concrete
Laundry trays, concrete
Lintels, concrete
Manhole covers and frames, concrete
Mantels, concrete

Mattresses for river revetment, concrete articulated
Meter boxes, concrete
Monuments, concrete
Panels and sections, prefabricated: concrete
Paving materials, prefabricated concrete, except blocks

Pier footings, prefabricated concrete
Ready-mixed concrete
Septic tanks, concrete
Shower receptors, concrete
Shrink-mixed concrete

Sills, concrete
Silo staves, cast stone
Silos, prefabricated concrete
Slabs, crossing: concrete
Steps, prefabricated concrete

Stone, cast concrete
Storage tanks, concrete
Tanks, concrete
Thresholds, precast terrazzo
Tombstones, precast terrazzo or concrete

Transit-mixed concrete
Well curbing, concrete
Window sills, cast stone

There are over 10,000 concrete-product plants making two or more of the above products. There are approximately 500 plants producing prestressed concrete, 5,000 producing precast concrete, and the remainder producing ready-mixed concrete.(29) These plants are distributed throughout the United States with the largest proportion of the volume in the north-central and southern sectors. Location of plants is dependent upon the construction requirements in the various areas.

Manufacturing Processes--

The manufacturing process for concrete products is relatively simple, as shown in Figure 47. Portland cement products are prepared by weighing out predetermined quantities of cement, aggregates (sand, lime, gravel), and water into a mixer and blending. This mixing is either accomplished on a truck mixer (hence the name transit- or ready-mixed) or at the site. After the batch has been blended to a desired consistency, it is poured into "forms" or "molds" for shaping. These formed concrete shapes are then "cured" until they have hardened sufficiently to be handled. Curing is done in either ambient air or by forced warm moist air. After the concrete has hardened sufficiently, the forms are removed and the products continue curing in air. These products are then stored until they can be loaded for truck or rail shipment.

Waste Streams--

Previous studies(27,28) indicate that this industry is not a major polluter and, as a result, little attempt has been made to reduce emissions. Before mixing, the emissions generally reflect the raw materials used. After mixing, the emissions are primarily a cementitious solid.

Particulate emissions from raw material unloading, batching, and mixing are discharged into the air-waste stream. The composition of these particulates generally reflects that of the raw materials.

Warm moist air curing also results in airborne emissions. These emissions are generally dependent upon the type of fuel used.

Pouring and form removal are both sources of water pollutants. In both cases, water is used for cleaning purposes. Usually this water is discharged

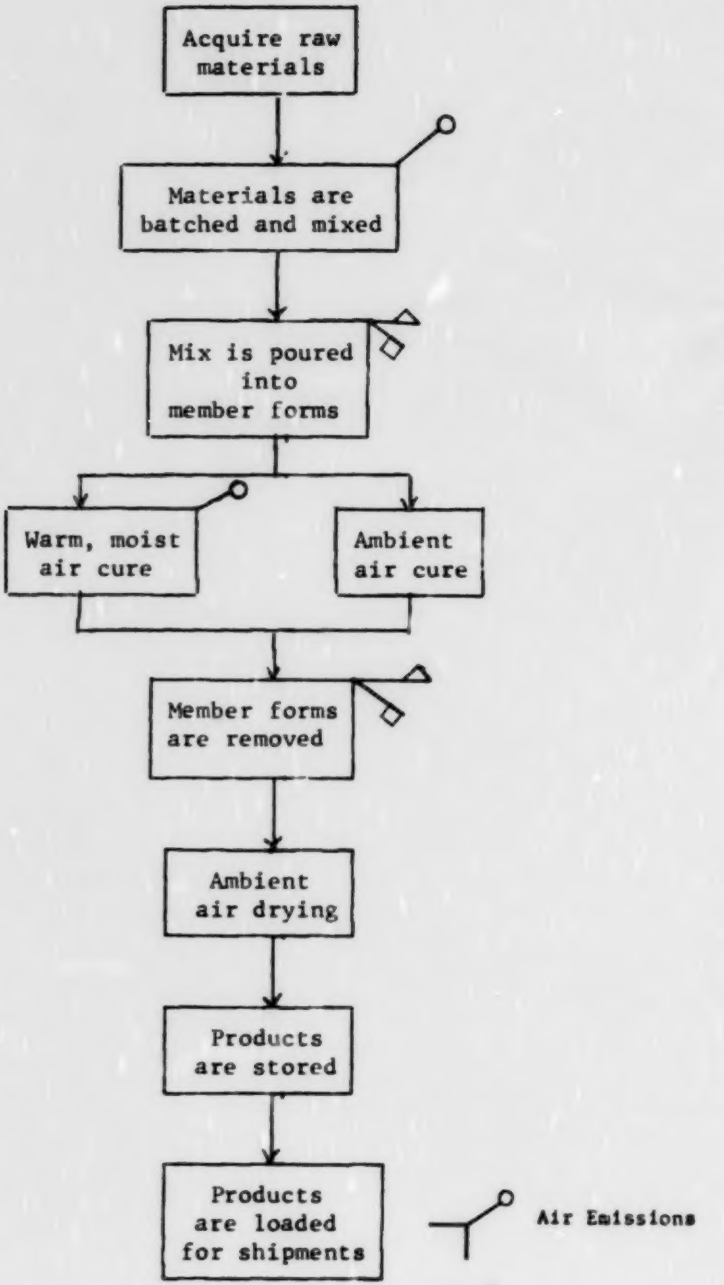
Acquire raw materials
Materials are batched and mixed
Mix is poured into member forms
Warm, moist air cure
Ambient air cure
Member forms are removed
Ambient air drying
Products are stored
Products are loaded for shipments
Air Emissions
Water Emissions
Solid Emissions

FIGURE 47. PROCESS STEPS FOR CONCRETE PRODUCTS.

although it is sometimes reused once or twice before discharge. Discarded water goes onto the ground, into a sewer or septic system, or into a settling pond. This water generally contains a cementitious sludge that could present a pollution problem.

In addition to the aforementioned water emissions, pouring and form removal are sources of solid wastes. These emissions consist of a cementitious solid and are normally discarded. Form materials may also contribute to the solid waste. These solid wastes could present a pollution problem.

Plaster of Paris and Gypsum Products

The manufacture of products from plaster of paris, papier mache, gypsum, or scagliola is contained in this industry. Major products include numerous types of statuary. Other products include:

Architectural sculptures, plaster of paris: factory production only
Art goods: plaster of paris, papier mache, and scagliola
Brackets, architectural: plaster of paris, factory production only
Columns: papier mache or plaster of paris
Ecclesiastical statuary: gypsum or papier mache, factory production only

Floor composition, magnesite
Flower boxes, plaster of paris: factory production only
Fountains, plaster of paris: factory production only
Gravel painting
Images, small: gypsum, clay, or papier mache, factory production only

Moldings, architectural: plaster of paris, factory production only
Ornamental and architectural plaster work: mantels, columns, etc.
Panels, papier mache or plaster of paris
Pedestals, statuary: plaster of paris or papier mache, factory only
Plaques: clay, plaster, or papier mache, factory production only

Sculptures, architectural: gypsum, clay, or papier mache, factory only
Statuary: gypsum, clay, papier mache, scagliola, and metal, factory only
Stucco
Synthetic stones, for gem stones and industrial use
Urns, gypsum or papier mache: factory production only
Vases, gypsum or papier mache: factory production only.

More than 40 companies produce these products.

The larger plaster of paris and gypsum-product companies are diversified companies or division of diversified companies engaged in other aspects of the construction industry or other business. These plants are distributed throughout the United States and are generally located according to the United States population distribution.(29,30)

Manufacturing Processes--

Plaster of paris and gypsum products are made from a slurry of water, gypsum, aggregate (sand, glass fibers), and a lightweight filler. In addition, surface-active agents are added to stucco and papier maché for bonding. After these raw materials are batched and mixed, they are poured into molds or forms for shaping. Initially, some of the excess water is removed by ambient air drying. When enough water is removed so that the structure can support itself, the forms are removed. After formal removal, the various products are either ambient-air or kiln dried. The products are then painted or stained with various commercial decorating agents. These decorating agents are ambient-air dried. Occasionally, a commercial sealant is sprayed over the decorated object. Once dry, the products are stored until they can be loaded for shipment. A process-flow diagram for this industry is shown in Figure 48.

Waste Streams--

Air emissions include particulates representative of the raw materials used. Other air emissions are dependent upon the type of fuel used for kiln drying. Water emissions include dissolved solids, suspended solids, and substances contributing to increased alkalinity. Solid-waste-stream emissions consist almost entirely of waste plaster of paris and gypsum products.

Raw-material receiving, batching, and mixing are sources of particulate air emissions. These emissions generally reflect the raw materials being used. Since the majority of these particulates can be captured in fabric filters, they are not expected to present a pollution problem.(31) Kiln drying could also result in airborne emissions. These emissions are generally dependent upon the type of fuel used.

Water wastes are emitted from batching, mixing, shaping, and decorating operations. In each of these areas, water is used for cleaning purposes. This water is sometimes reused before discharge. Discarded water is generally discharged into a sewer or septic system or into a settling pond. This water generally contains dissolved solids, suspended solids, and substances contributing to increased alkalinity. A previous study(27) indicated that this could present a pollution problem.

Solid wastes are discharged from shaping and decorating operations. These emissions consist of a cementitious material and are generally discarded. This solid waste could present a pollution problem.

Abrasive Buffs

The production of abrasive buffs from various kinds of natural and synthetic materials is included in this industry. Products manufactured by this industry include cloth and paper buffs, as well as sandpaper and soap-impregnated scouring pads and sponges.

There are numerous manufacturers of these products distributed throughout the United States.

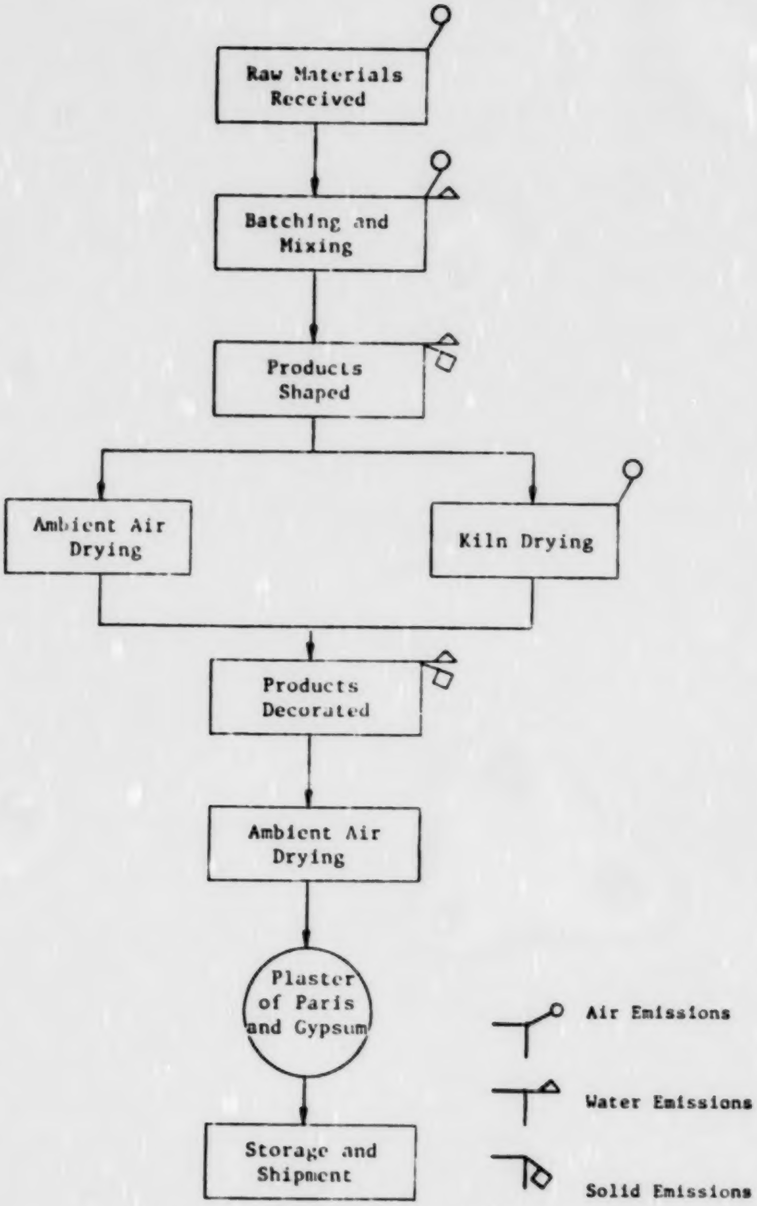
Raw Materials Received
Batching and Mixing
Products Shaped
Ambient Air Drying
Kiln Drying
Products Decorated
Ambient Air Drying
Plaster of Paris and Gypsum
Storage and Shipment
Air Emissions
Water Emissions
Solid Emissions

FIGURE 48. PROCESS FLOW DIAGRAM FOR THE PLASTER OF PARIS AND GYPSUM PRODUCTS INDUSTRY.

Manufacturing Processes--

Most of these products undergo similar processing operations, as shown in Figure 49. Abrasive buffs are manufactured from bricks, cloth, paper, steel, sticks, and stones using both natural and synthetic abrasive grains. Some of the more common grains used today include garnet, emery, aluminum oxide, and flint. These various grains are attached to the buff material by using an epoxy and pressing. For soap-impregnated scouring pads and sponges, the buff material usually is immersed in a soap solution under vacuum. All of these buffs are then air dried, packaged, and stored until they can be loaded for shipment.(32)

Waste Streams--

Air emissions include particulates representative of the raw materials used. Water emissions include soap particulates. Solid-waste-stream emissions consist almost exclusively of waste buffs.

Raw-material receiving, batching, and mixing operations are sources of particulate emissions. These operations, however, are usually done under hoods which are usually discharged through fabric filters. Thus, few of these particulates are discharged into the atmosphere.

Soap impregnation of buffs is the major source of water pollutants. Water is generally used in the soap slurry as well as for cleaning. The slurry, however, is reused and recycled. Thus, the only emissions would be from cleaning. This water is expected to contain the same ingredients found in the soap as well as some metal and sponge fibers, each of which could present a pollution problem.

Solids are generally emitted from batching, mixing, pressing, and impregnating operations. These emissions generally consist of a cementitious material (epoxy) and waste buffs. Small amounts of these solids are reused or recycled. Thus, this solid waste could present a pollution problem.

Abrasive Wheels

The production of abrasive wheels from diamonds and synthetic materials is included in this industry. There are numerous producers of these products distributed throughout the United States. Most abrasive wheel manufacturing facilities, however, are located near their raw material supply.

Manufacturing Processes--

Most of these products undergo similar processing operations, as shown in Figure 50. Abrasive grains (natural diamond and synthetic materials) are combined with a resinous ceramic binder material and pressed or poured into desired shapes. Many of these pieces are heated to elevated temperatures (e.g., 2375 F). Pressed pieces that are not heated are usually dried in fuel-fired dryers. After firing and drying, these pieces are cooled in ambient air and stored until they can be loaded for shipping by rail or truck.(32)

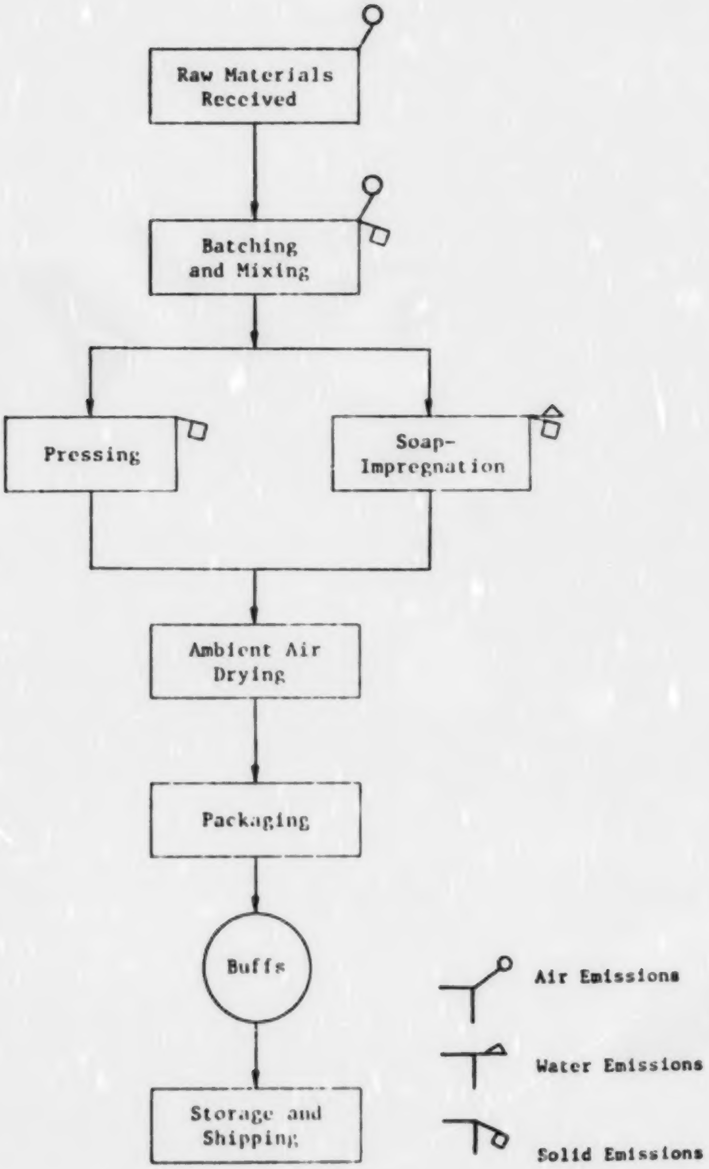
Raw Materials Received
Batching and Mixing
Pressing
Soap-Impregnation
Ambient Air Drying
Packaging
Buffs
Storage and Shipping
Air Emissions
Water Emissions
Solid Emissions

FIGURE 49. PROCESS FLOW DIAGRAM FOR THE ABRASIVE BUFFS INDUSTRY.

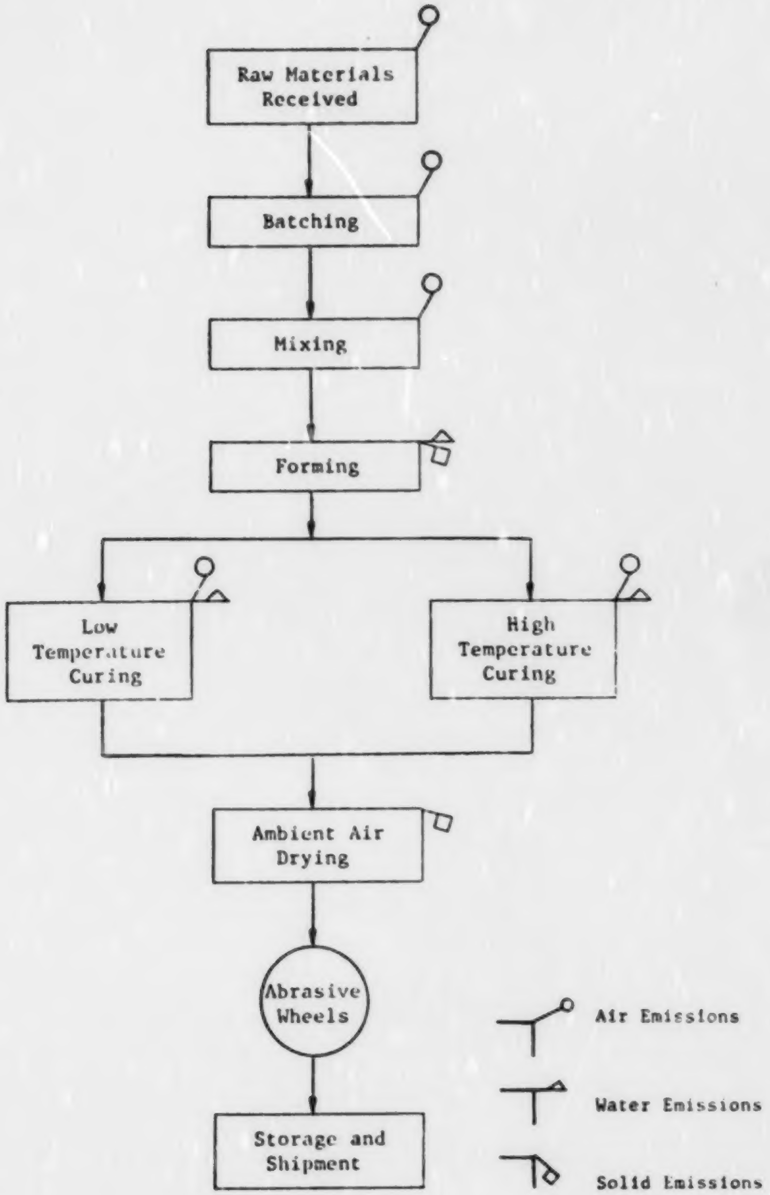
Raw Materials Received
Batching
Mixing
Forming
Low Temperature Curing
High Temperature Curing
Ambient Air Drying
Abrasive Wheels
Storage and Shipment
Air Emissions
Water Emissions
Solid Emissions

FIGURE 50. PROCESS FLOW DIAGRAM FOR THE ABRASIVE WHEEL INDUSTRY.

Waste Streams--

The manufacture of abrasive wheels involves air, water, and solid-waste streams. Air emissions include abrasive grain particulates. Other air emissions are dependent upon the type of fuel used for drying and firing. Water emissions include abrasive grain particulates. Solid-waste-stream emissions consist almost exclusively of a cementitious sludge.

Raw material receiving, batching, and mixing are sources of particulate emissions into air waste streams. These particulates are composed of fine-grained raw materials. Since these operations are usually hooded, the streams generally pass through fabric filters. Thus, few of these particulates are discharged into the atmosphere.

Forming and curing operations are both sources of water pollutants. For curing, water is used for cooling purposes. This water is generally reused numerous times before discharge. Discarded water is generally discharged into a sewer or septic system or into a settling pond. This water generally contains suspended particulates and heat, each of which could present a problem.

Water is used during the forming operations primarily for cleaning purposes. This water is used once or twice before discharge into a sewer or septic system or into a settling pond. Discarded water could contain both suspended and dissolved solids which could present a pollution problem.

Solids are generally emitted from forming and ambient air drying operations. These emissions consist of a cementitious material (hardened resins, cements, and discarded abrasive wheels). In general, few wheels are disposed of, so this is not considered a pollution problem. However, little of the discarded epoxy is reused or recycled and it could present a pollution problem.

Asbestos Textiles

Textiles made from asbestos are included in this industry. Major products include blankets, cloth, and felt. Other asbestos textile products are:

Carded fiber
Cord
Rope
Table pads and padding
Tape
Thread
Wick
Yarn.

There are at least 11 asbestos textile manufacturers operating 15 plants distributed throughout the United States. Most facilities, however, are located near their raw material supply.

Manufacturing Processes--

In making asbestos textile products, no process water is used with the asbestos fibers. Instead, a variety of organics, such as vinyl resins, textile coatings, and solvents are batch ingredients. These products are made by the usual textile processing methods, as shown in Figure 51. After asbestos fibers are dispersed in a carrier material, the product is shaped by a pressing or extruding operation. Shaped products are then cured by either high-pressure steam, low-pressure steam, ambient air, or chemical reaction. After cooling, products are stored until they can be loaded for truck or rail shipment.(33)

Waste Streams--

Although this industry is, in general, not a major polluter, an attempt has been made to reduce asbestos fiber emissions. Air emissions include minor amounts of asbestos fiber. Other air emissions are dependent upon the type of fuel used for curing. Water emissions include suspended and dissolved solids. Solid waste-stream emissions consist almost exclusively of asbestos fibers encased in resin.

Raw material receiving and dispersing are sources of particulate air emissions. These operations, however, are generally conducted under a hood which usually is discharged through fabric filters. As a result, few of these particulates are discharged into the atmosphere.

High- and low-temperature curing operations also result in airborne emissions. These emissions are generally dependent upon the type of fuel used.

Curing and cleaning operations are both sources of water pollutants. For curing, water is primarily used for cooling purposes. This water is generally reused numerous times before discharge. Discarded water is generally discharged into a sewer or septic system or into a settling pond. This water generally contains suspended particulates and is not expected to present a pollution problem.

Cleaning water is rarely reused or recycled and is generally discharged into municipal sewer systems. This water contains both suspended and dissolved solids and could present a pollution problem.(34)

Solids are generally emitted from the forming and cooling operations. These emissions consist of a cementitious material and are generally discarded. This solid waste could present a pollution problem.

Asbestos Insulation

Manufacture of high-temperature insulation from asbestos is contained in this industry. Products include:

Blankets, insulating for aircraft
Boiler covering

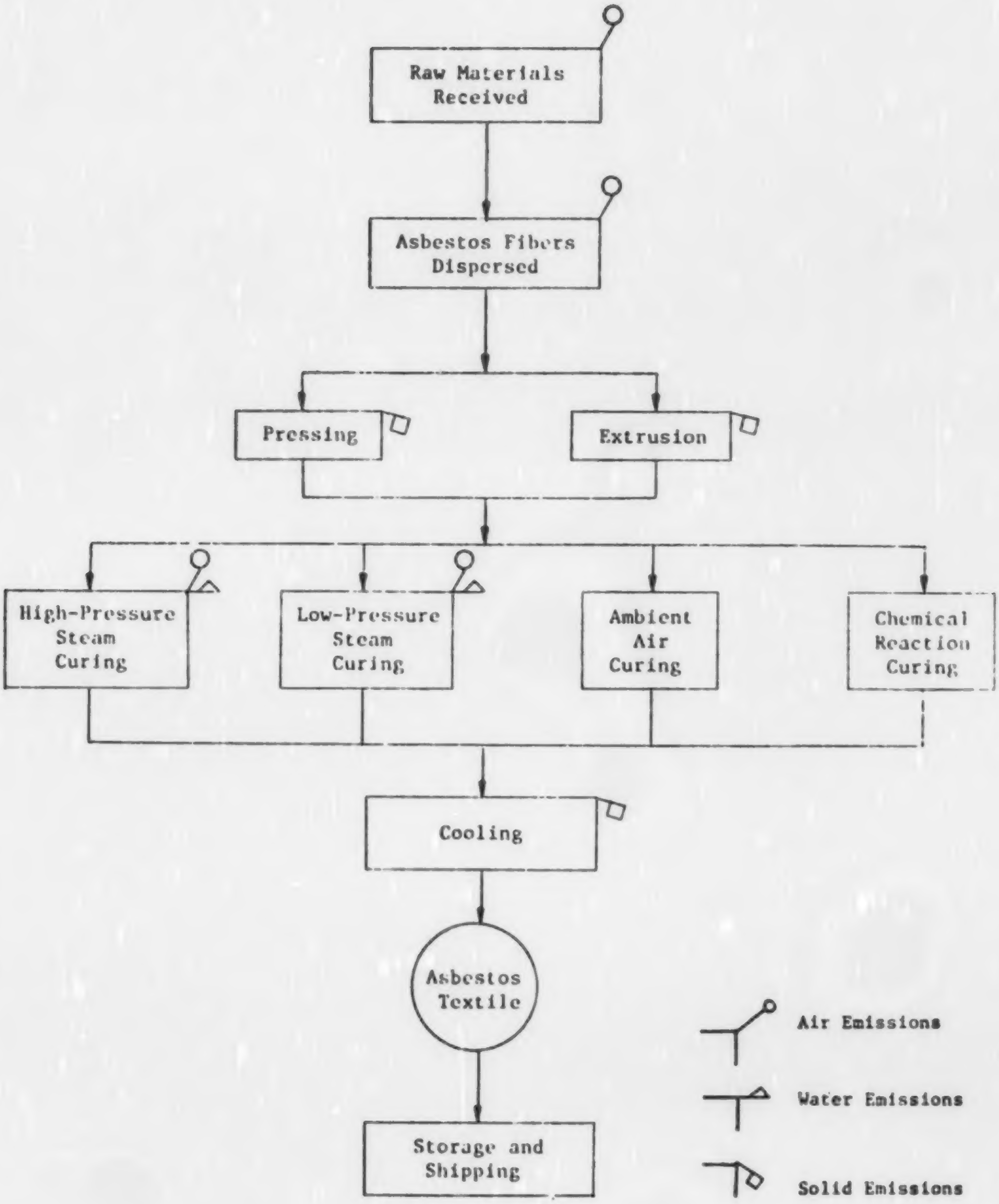
Raw Materials Received
Asbestos Fibers Dispersed
Pressing
Extrusion
High-Pressure Steam Curing
Low-Pressure Steam Curing
Ambient Air Curing
Chemical Reaction Curing
Cooling
Asbestos Textile
Storage and Shipping
Air Emissions
Water Emissions
Solid Emissions

FIGURE 51. PROCESS FLOW DIAGRAM FOR THE ASBESTOS TEXTILE INDUSTRY.

Insulsleeves (foundry materials)
Molded asbestos
Pipe and boiler covering
Tubing.

This industry consists of over 14 companies operating some 20 manufacturing plants.

Manufacturing Processes--

Asbestos insulation is made from asbestos fibers combined with an inorganic or resinous binder, as shown in Figure 52. After mixing, the coated asbestos fibers are extruded into a mat, poured into forms, or cast into tubing. These shaped products are usually cured under high-pressure steam. After cooling, the cured product is then subjected to appropriate finishing operations for the particular product, such as compressing or the application of a backing sheet (i.e., aluminum foil). Insulation is then packaged and stored until it can be loaded for truck or rail shipment.

Waste Streams--

Waste streams involved in the manufacture of asbestos insulation may include air, water, and solid. This industry is generally not considered a major polluter and, as a result, little attempt has been made to reduce emissions. Air emissions include minor amounts of asbestos fibers. Other air emissions are dependent upon the type of fuel used for curing.

Water emissions include dissolved and suspended solids. Solid-waste-stream emissions consist almost exclusively of coated asbestos fibers.

Raw material receiving and curing are sources of air particulate emissions. Raw material receiving, however, is usually done under a hood which discharges through fabric filters. As a result, few of these particulates are discharged into the atmosphere.

Curing operations also result in airborne emissions. These emissions are generally dependent upon the type of fuel used.

Cleaning after forming operations results in water emissions. Cleaning water is rarely reused or recycled and is generally discharged into municipal sewer systems. This water contains dissolved and suspended solids and could present a pollution problem.(27)

For curing, water is primarily used for cooling purposes. This water is generally reused numerous times before discharge. Discarded water is generally discharged into a sewer or septic system or into a settling pond. This water generally contains suspended particulates and is not expected to present a pollution problem.

Solids are generally emitted from the mixing and forming operations. These emissions consist of resin-encased asbestos fibers and are generally discarded. This solid waste could present a pollution problem.

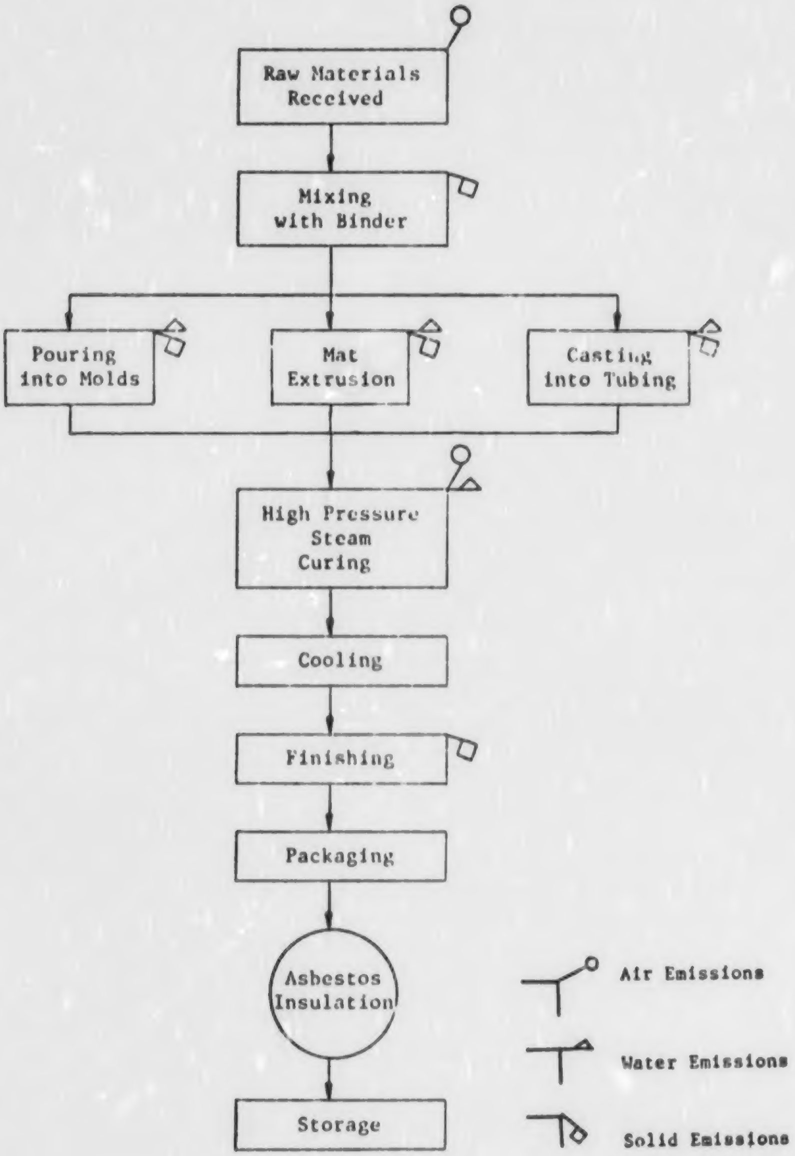
Raw Materials Received
Mixing with Binder
Pouring into Molds
Mat Extrusion
Casting into Tubing
High Pressure Steam Curing
Cooling
Finishing
Packaging
Asbestos Insulation
Storage
Air Emissions
Water Emissions
Solid Emissions

FIGURE 52. PROCESS FLOW DIAGRAM FOR THE ASBESTOS INSULATION INDUSTRY.

Inorganic Acoustical and Building Insulation*

This industry includes the manufacture of acoustical and low-temperature building thermal insulation. Insulation fiber glass accounted for 66 percent of the total tonnage production in 1971. Other products include:

- Acoustical board and tile
- Ceramic fiber batts, etc.
- Glass wool batts, etc.
- Mineral wool, batts, etc.

Relatively few companies manufacture inorganic acoustical and building insulation. These plants, which are distributed throughout the United States, are relatively large. The smallest produces on the order of 5 million pounds of insulation per year.(35)

Manufacturing Processes--

The inorganic acoustical and building insulation contained in this category are made from ceramic fiber, fiber glass, glass wool, and mineral wool. These fibers are combined with a thermosetting phenolic binder in a diluted aqueous solution, as shown in Figure 53. This binder sometimes also contains a colored dye. After mixing, the fibers are formed into a mat which is cured and cooled. The cured mat is then subjected to appropriate finishing operations for the particular product, such as compressing or the application of a backing sheet such as aluminum foil. Insulation is then packaged and stored until it can be loaded for truck or rail shipment.

Waste Streams--

Air emissions include glass fibers. Other air emissions are dependent upon the type of fuel used for curing. Water emissions include suspended solids. Solid-waste-stream emissions consist almost exclusively of glass fibers.

Raw material receiving and curing are sources of air particulate emissions. Raw material receiving, however, is usually done under a hood which discharges through fabric filters. As a result, few of these particulates are discharged into the atmosphere.

Curing operations also result in airborne emissions. These emissions are generally dependent upon the type of fuel used.

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* This classification does not include foam-type insulation.

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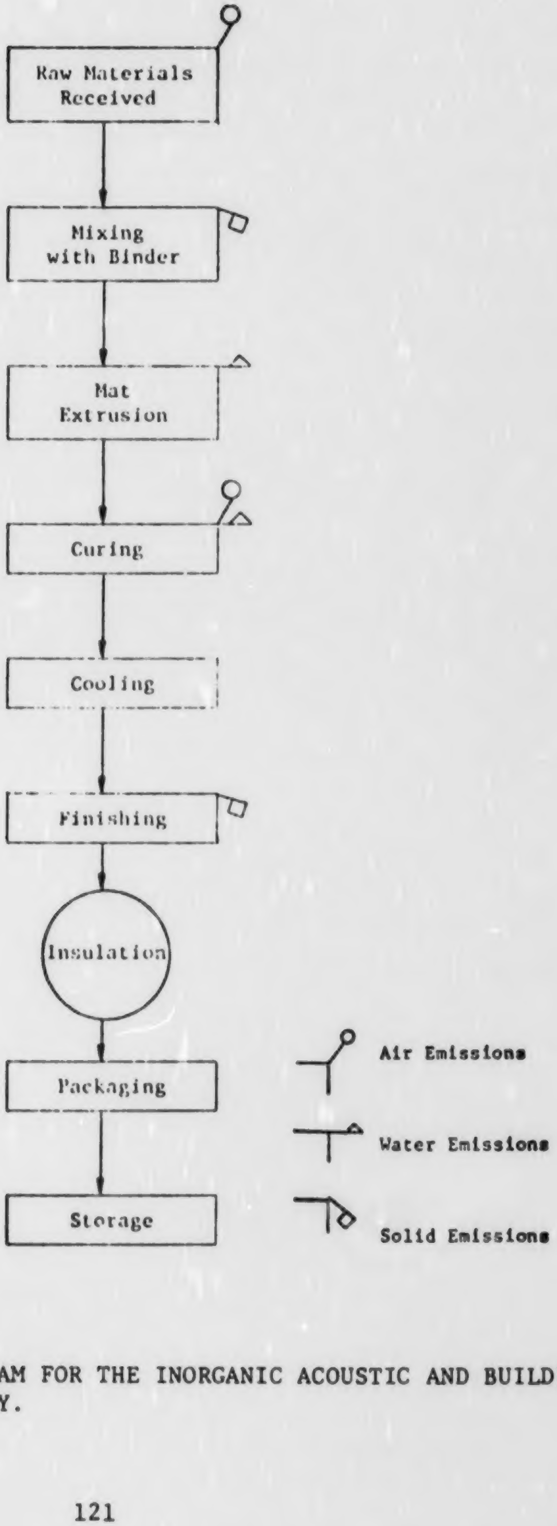

Raw Materials Received
Mixing with Binder
Mat Extrusion
Curing
Cooling
Finishing
Insulation
Packaging
Storage
Air Emissions
Water Emissions
Solid Emissions

FIGURE 53. PROCESS FLOW DIAGRAM FOR THE INORGANIC ACOUSTIC AND BUILDING INSULATION INDUSTRY.

Cleaning and curing operations result in water emissions. For curing, water is primarily used for cooling purposes. This water is generally reused numerous times before discharge. Discarded water is generally discharged into a sewer or septic system or into a settling pond. The curing water generally contains suspended particulates and is not expected to present a pollution problem. Phenolic compounds are also present in the wastewaters.

Cleaning water is rarely reused or recycled and is generally discharged into municipal sewer systems. This water contains suspended solids and could present a pollution problem.(35)

Solids are generally emitted from the mixing and forming operations. These emissions consist of resin-encased fibers and are generally discarded. This solid waste could present a pollution problem.

Inorganic Electrical Insulation

The manufacture of inorganic electrical insulation from mica and fused quartz is contained in this industry. Two major products are laminated mica and quartz tubing.

Relatively few companies manufacture electrical insulation. These plants, which are distributed throughout the United States, are believed to be relatively large.(15)

Manufacturing Processes--

Laminated mica and fused quartz tubing are made from a series of relatively simple operations as shown in Figure 54. These operations include: raw material receiving, batching, and mixing; forming; heat treating; cooling; finishing; and packaging. Laminated mica is primarily made from sheet mica which is then impregnated with a monomer. Sheets of mica are generally stacked before high-pressure impregnation. After forming, they are shaped by punching or cutting and then finished. Laminated mica insulation is packaged and stored until it can be loaded for shipment.(28)

Fused quartz, on the other hand, is made from silica (SiO_2) and an organic binder. After mixing, the tubes are cast or pulled and then the silica is fused at a high temperature (2800 F). Upon cooling, tubes are sized and finished. Fused quartz insulation is then packaged and stored until it can be loaded for shipment by rail or truck.(28)

Waste Streams--

Air emissions include silica (SiO_2) and mica particulates. Other air emissions are dependent upon the type of fuel used for heat treatment. Water emissions include dissolved and suspended solids. Solid-waste-stream emissions consist almost exclusively of mica and fused quartz.

Raw material receiving, batching, and mixing are sources of air particulate emissions. These operations, however, are usually done under hoods which discharge through fabric filters. As a result, few of these particulates

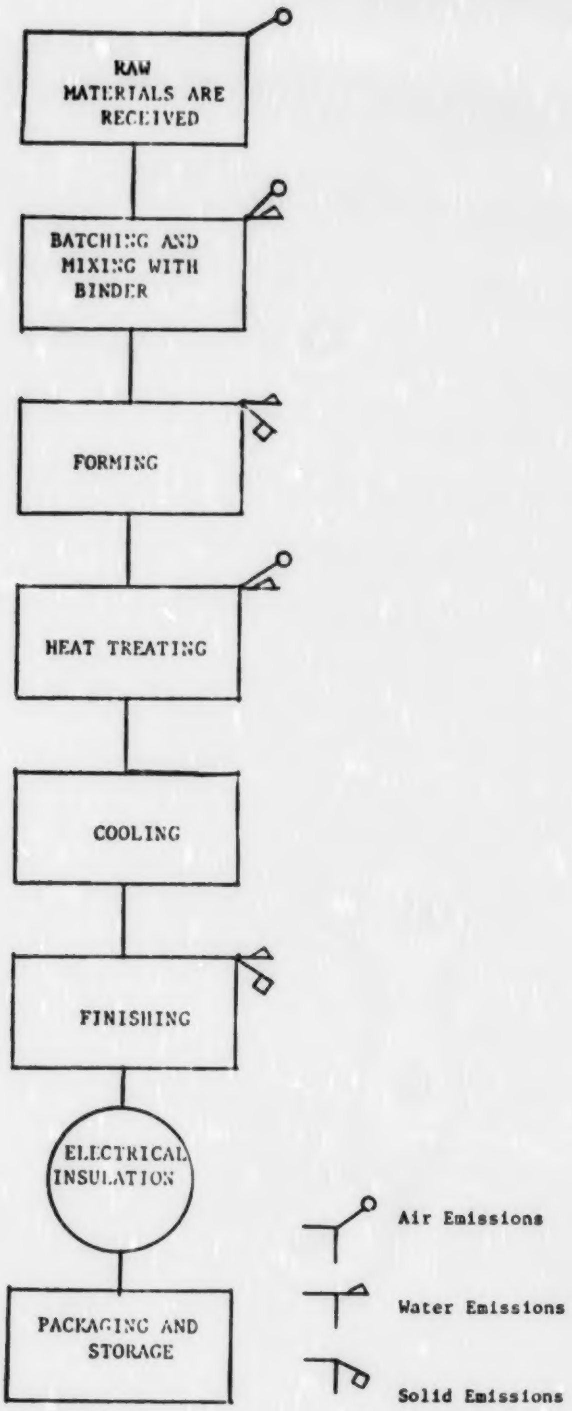
RAW MATERIALS ARE RECEIVED
BATCHING AND MIXING WITH BINDER
FORMING
HEAT TREATING
COOLING
FINISHING
ELECTRICAL INSULATION
PACKAGING AND STORAGE
Air Emissions
Water Emissions
Solid Emissions

FIGURE 54. PROCESS FLOW DIAGRAM FOR THE INORGANIC ELECTRICAL INSULATION INDUSTRY.

are discharged into the atmosphere.

Heat-treating operations also result in airborne emissions. These emissions are generally dependent upon the type of fuel used.

Cleaning and heat-treating operations result in water emissions. In heat treating, water is primarily used for cooling purposes. This water is reused numerous times before discharge. Discarded water is normally discharged into a sewer or septic system or into a settling pond. This water generally contains suspended particulates and is not expected to present a pollution problem.

Cleaning water is rarely reused or recycled and is generally discharged into municipal sewer systems. This water contains suspended solids and could present a pollution problem.

Solids are normally emitted from the forming and finishing operations. These emissions consist of laminated mica and fused quartz chunks and are generally discarded. This solid waste could present a pollution problem.

FABRICATED METAL PRODUCTS

This major group includes establishments engaged in fabricating ferrous and nonferrous metal products such as metal cans, tinware, hand tools, cutlery, general hardware, nonelectric heating apparatus, fabricated structural metal products, metal forgings, metal stampings, ordnance (except vehicles and guided missiles), and a variety of metal and wire products not elsewhere classified. Certain important segments of the metal-fabricating industries are classified in other major groups, such as machinery, transportation equipment, including tanks, professional scientific and controlling instruments, watches and clocks, and jewelry and silverware.

There were 29,526 establishments in 1972 primarily engaged in producing metal products ranging from cans and nuts and bolts to large structures made up from steel structurals (e.g., bridges). These establishments employed 1.454 million people and shipped products valued at $51.74 billion.(1)

Manufacturing Processes--

A relatively limited number of unit operations are used in various combinations to manufacture the great diversity of products that are fabricated by this industry. These unit operations and the types of wastes they generate are discussed first. Several flow charts are then presented that illustrate the sequence of operations in typical metal-fabrication processes.

Melting and Casting of Metals--Metals are generally melted and cast by companies involved in the foundry industry, but there are many metal-fabrication companies that have captive melting and costing operations for producing fabricated metal products. The melting and costing operations have continued to be identified as sources of air, water, and solid-waste pollution. The chief forms of pollution come from the vaporization of metal and the slags formed during melting and from the burn-off of binders during the solidification of metals in the sand molds. Solid wastes include the hydrocarbons which burn off or are vaporized during casting. Dust-collection systems in use at many modern foundries have been effective in substantially reducing the airborne solids coming from the melting operations. Control of the gaseous emissions is accomplished by controlling the compounds used in sand and core binders. The American Foundrymen's Society issues several health and safety guides especially related to some of the more noxious chemicals (e.g., urethane resins). Some of such compounds are used for core binders and can cause skin irritations while in concentrated liquid or vapor forms. Such compounds include toluene, phenol, triethylamine, alkyd oils, polyesters, and polyethers. These are but a few of the hydrocarbons associated with high-quality core making. Other compounds such as ammonia, isocyanates, and alcohols are also used in foundries. Many of such compounds are baked off in core ovens and vented to the atmosphere.

The foundry industry is associated with contributions to all waste streams and has been the subject of review by OSHA representatives. Presumably, the foundries captive among the fabricated metal products industries are also experiencing similar reviews.

Welding and Torch Cutting of Metals--As a process, welding is applied by perhaps half of the industries engaged in fabricating metal products, either to the products or to the construction of tooling used to manufacture metal components. Dies used in forging, die casting, sheet forming, and stamping are generally welded either in the form of hard facing or as a repair method. The various welding processes most commonly used include stick electrode welding, sub-arc welding, metal inert gas welding, and resistance welding (usually the flash butt types). There are many other welding processes. Associated with welding is the oxy-gas torch cutting of metals and especially the carbon electrode oxygen process of cutting metals (sometimes referred to as arc-air cutting). Both of these processes can result in the development of large volumes of dust-like materials which can cause much concern among those working nearby. The carbon arc-air/oxygen process is by far the most productive of dust which contains various metal oxides, depending on the metal being cut. Of course slag forms also from the molten metal exposed to air. Thus, the waste streams which are developed from these processes include metal oxides, slags, and silicates.

The majority of the dust-like wastes are usually confined to the immediate area of the individuals performing the operations but the stick electrode welding and the arc-air cutting can result in more widely scattered waste which is very difficult to control unless the welding is performed in booths or tents.

Soldering is also included as a means of fastening metal, but as used commercially it does not produce waste streams. Any runoff goes back into the bath. There may be some hazard, however, in heating soldered scrap because of the lead contained in solder alloys.

Metalworking operations--There are several types of metalworking operations involved in the manufacture of fabricated metal products including

Forging
Rolling
Extrusion
Rollforming
Spinning
Stamping
Blanking
Shear forming
Drawing
Machining.

These processes are carried out either cold or hot depending on the material being formed. Hot forming usually involves the use of lubricants which are either oil-base or water-base suspensions of graphite applied to the tooling and workpieces and are, therefore, likely to produce airborne solids and hydrocarbons. The cold-forming processes usually are lubricated with solid films including stearate soaps and molybdenum disulfide. These lubricants are usually applied in batch tanks prior to the metal-forming process.

Furnaces used for the hot-forming operations are usually fueled with natural gas, oil, or electricity, oil being associated with the highest levels of smoke and unburned hydrocarbons. Most fuel-fired furnaces are less than 15 percent efficient and a large percentage of the furnaces are not equipped with sufficient controls to ensure complete combustion of the fuels. On the other hand, much of the unburned fuel is burned after the products of combustion leave the furnaces, thereby minimizing the potentially adverse effects of CO and other partially combusted products which would otherwise cause pollution problems.

Lubricating--While is truly part of metal-forming processes, it is identified as a distinct process step because of the potential environmental impact. Some of the best lubricants contain such metal oxides as cadmium oxide and lithium oxide and certain copper-containing compounds. Such compounds are toxic to varying degrees. Thus, most companies have abandoned their uses except for rare cases in which the greases are not likely to be exposed to conditions which would cause them to vaporize or otherwise get into the environment. Major emphasis during the past few years has been directed to the use of water-base lubricants wherever possible to avoid the smoke from oil-base compounds.

Cold forming requires lubrication also but the compounds are different, usually involving water solutions or suspensions of graphite or compounds of the stearate soap types. The waste streams coming from these lubricants usually are in the wastewater with very little air pollution. Current practices for dealing with soaps include the use of settling tanks to convert the compounds to solids which are then disposed of in land fills.

Thermal Treatments--A wide variety of thermal treatments are applied to fabricated metal products, including the heating for hot working, annealing, heat treating, baking (drying of slurries and coatings), and furnace brazing. Depending on the products being heated and the purposes, heating operations can result in a variety of pollutants to the airstreams. Products of combustion, evaporated solvents, and other gaseous types are sometimes rather plentiful near furnaces/ovens being used for this purpose.

Surface Treatments and Coatings--Surface treatments which are applied to the fabricated metal products include sand blasting, polishing, and various forms of acid or caustic pickling. Sand blasting results generally in waste products which are eventually disposed of in land fill areas (solid waste). Polishing usually results in water suspensions of solids which either go directly into the waste streams or are passed through settling basins which in turn are periodically cleaned of sediments that are used for land fill. The surface treatments which can result in the most noticeable water pollution are the pickling operations. Many companies use reaction ponds to neutralize the pickle liquors before diluting and flushing them into the waste streams.

Surface-coatings processes are used to apply a protective coating onto the surface of fabricated metal products and include electroplating, painting/varnishing/lacquering, enameling, bonderizing, tinning, and galvanizing.

All of these processes can result in waste streams, especially the electroplating and painting processes. Electroplating solutions contain various metal salts which can reach the waste streams if not neutralized and removed. The use of electrostatic painting has substantially reduced the entry of over-spray into the waste streams. Otherwise, the spray booths are flushed with water curtains which carry away the over-spray to either settling basins or directly to the sewage systems. The solvents/carriers of these coatings generally evaporate and are exhausted either directly to the air or after baking in ovens which are vented to the air.

Typical Processes--

Generalized flow charts are shown for production of the following fabricated metal products:

Product	Figure Number
Metal cans	55
Hand tools, forged	56
Hand tools, cast	57
Plumbing fixtures, zinc	58
Fabricated structural metal products - bridges	59
Screw-machine products - bolts, nuts	60
Steel forgings	61
Galvanizing for the trade	62
Cartridge cases	63

These charts show the manner in which unit operations are combined for the various processes and show the natures of waste streams arising from the operations.

Waste Streams--

Table 6 summarizes the relative levels of air, water, solid-waste, and noise pollution arising from the various unit operations typically associated with the manufacture of fabricated metal products. Also shown is a relative measure of whether a particular waste is general throughout the plant or

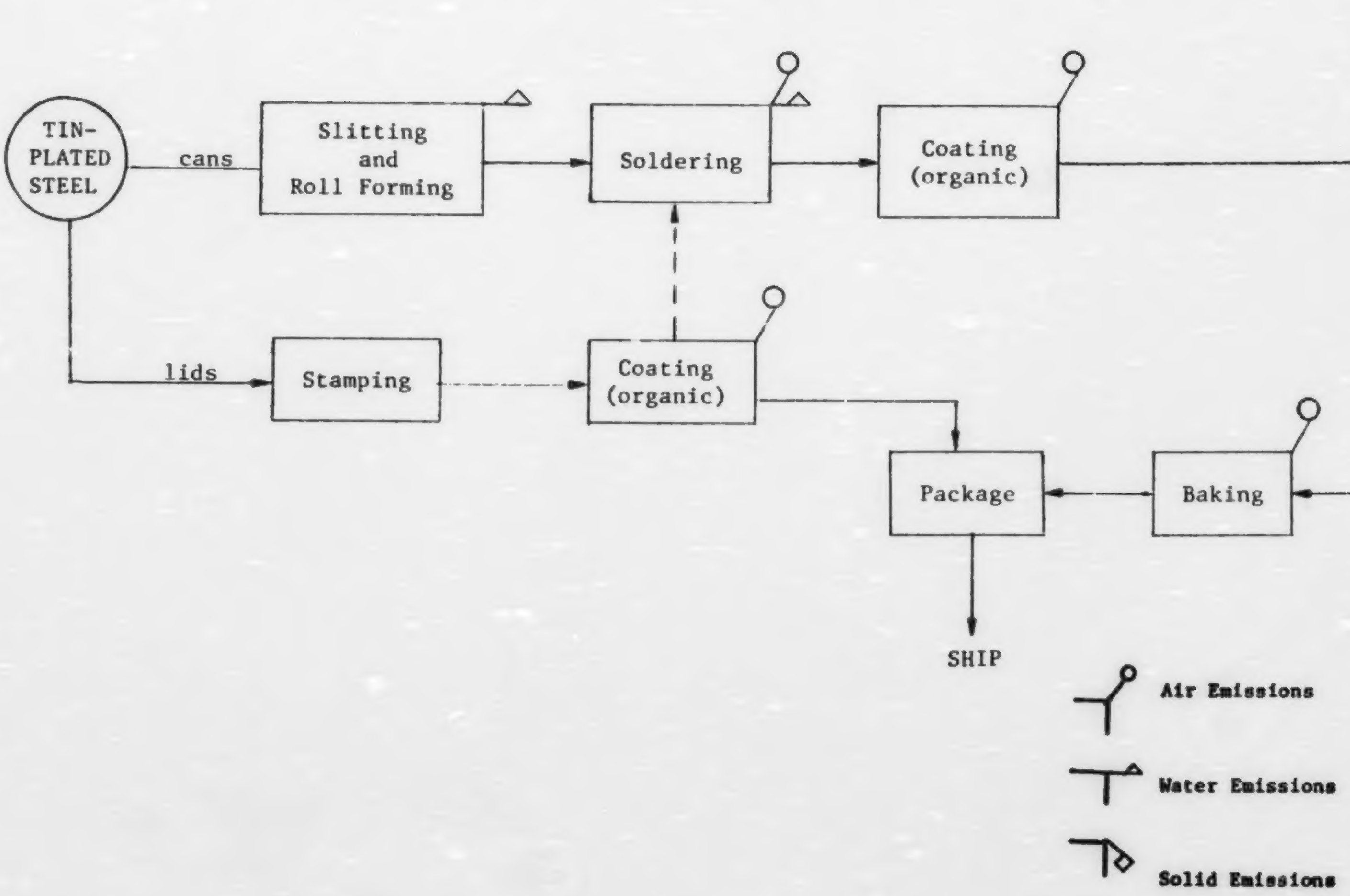
TIN-
PLATED
STEEL
cans
lids
Slitting and Roll Forming
Stamping
Soldering
Coating (organic)
Coating (organic)
Package
Baking
SHIP
Air Emissions
Water Emissions
Solid Emissions

FIGURE 55. METAL CANS.

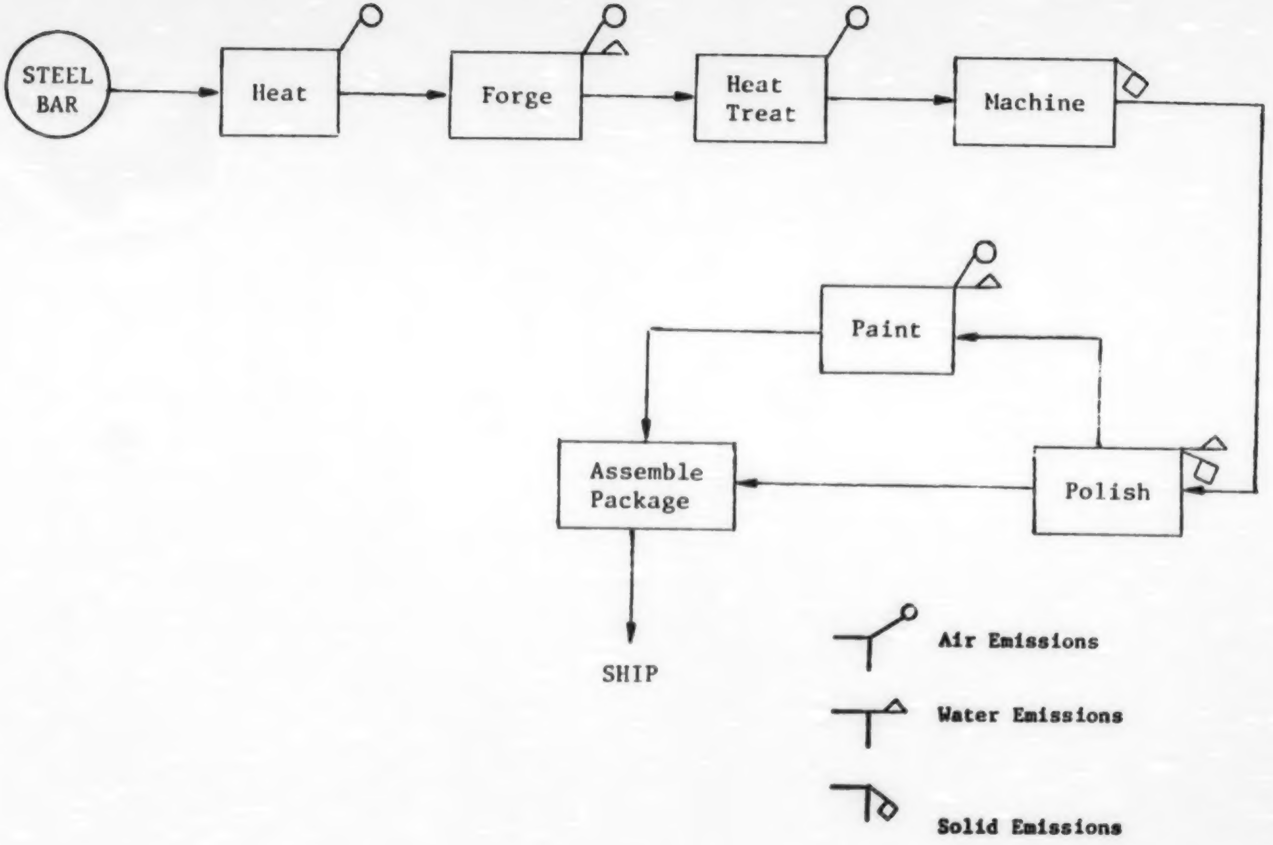
STEEL BAR
Heat
Forge
Heat Treat
Machine
Paint
Assemble Package
Polish
SHIP
Air Emissions
Water Emissions
Solid Emissions

FIGURE 56. HAND TOOLS, FORGED.

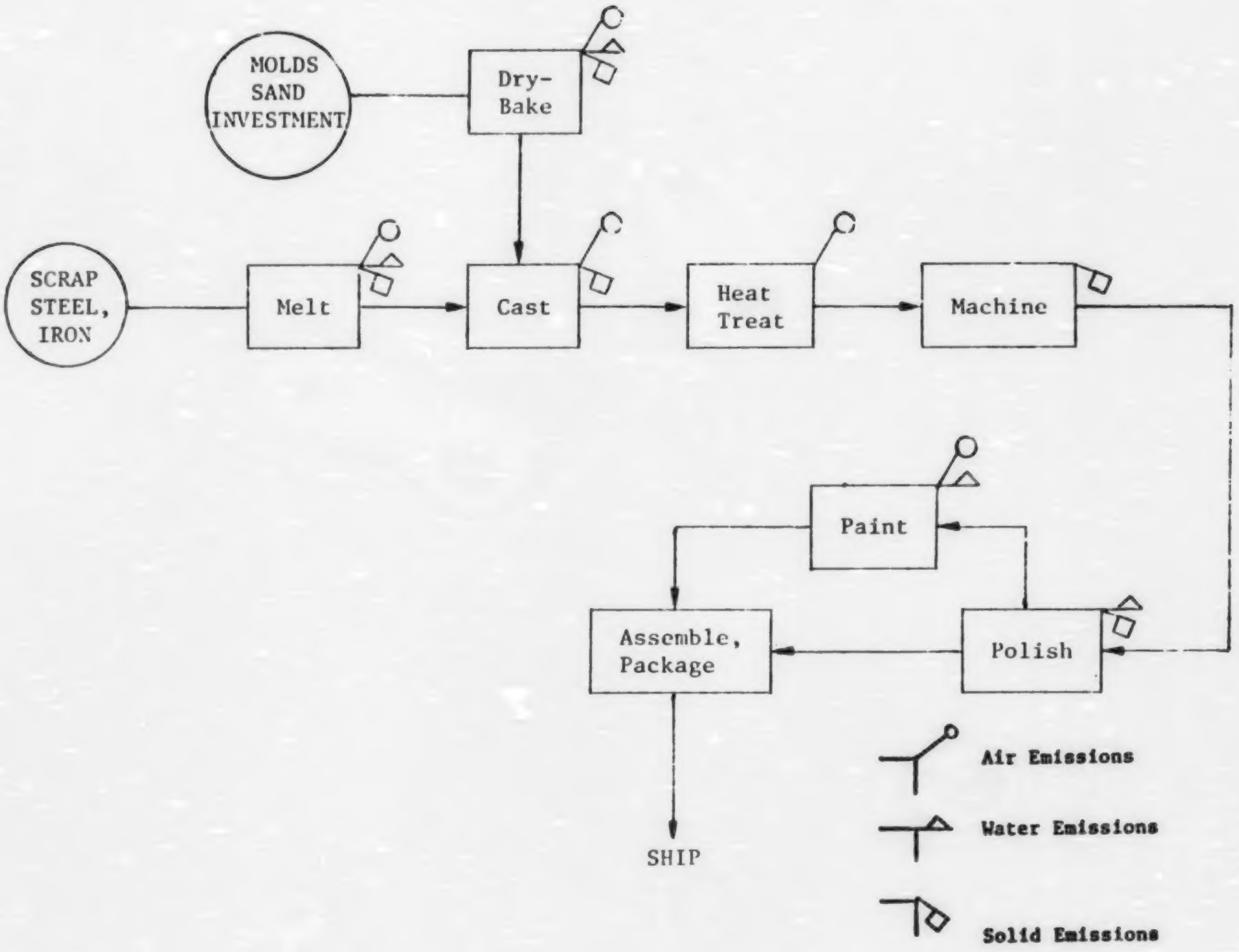
MOLDS
SAND
INVESTMENT
Dry-
Bake
SCRAP
STEEL,
IRON
Melt
Cast
Heat
Treat
Machine
Paint
Assemble,
Package
Polish
SHIP
Air Emissions
Water Emissions
Solid Emissions

FIGURE 57. HAND TOOLS, CAST.

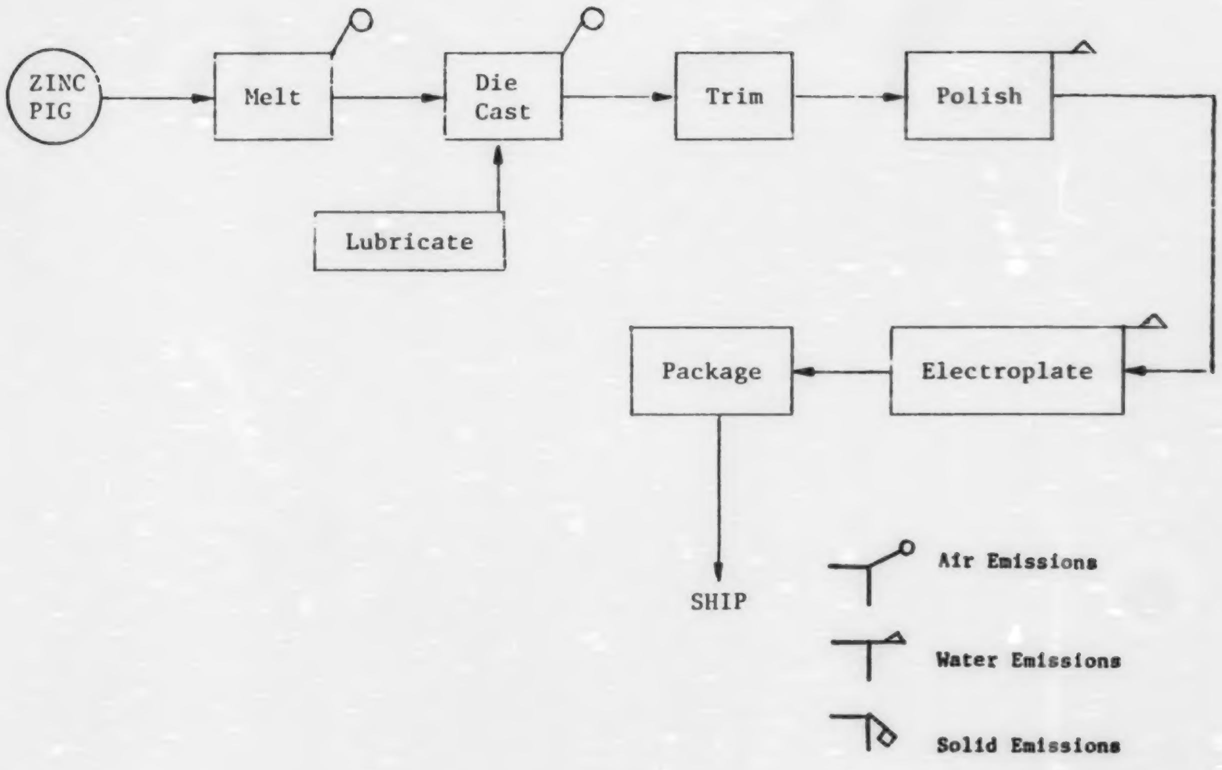
ZINC PIG
Melt
Die Cast
Lubricate
Trim
Polish
Electroplate
Package
SHIP
Air Emissions
Water Emissions
Solid Emissions

FIGURE 58. PLUMBING FIXTURES - ZINC.

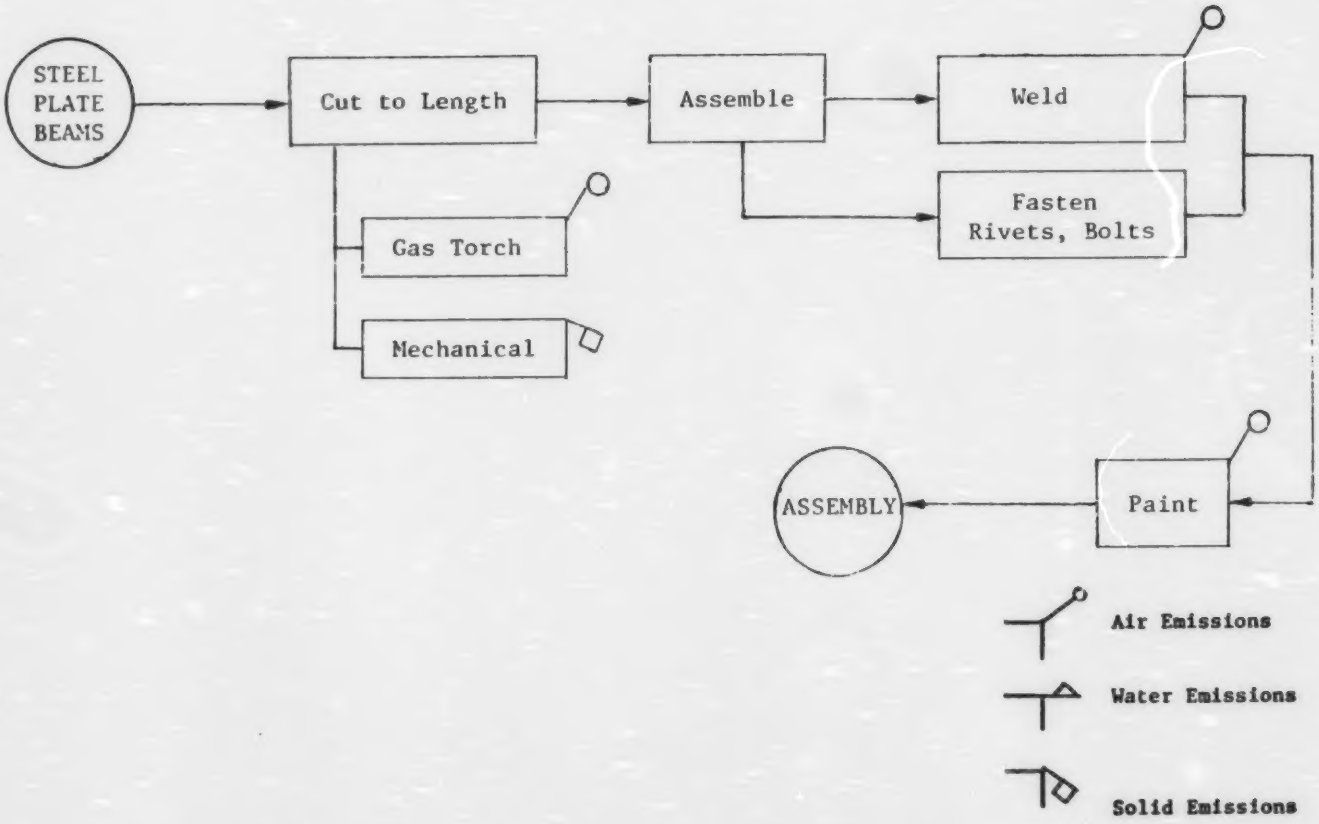
STEEL PLATE BEAMS
Cut to Length
Gas Torch
Mechanical
Assemble
Weld
Fasten Rivets, Bolts
Paint
ASSEMBLY
Air Emissions
Water Emissions
Solid Emissions

FIGURE 59. FABRICATED STRUCTURAL METAL PRODUCTS - BRIDGES.

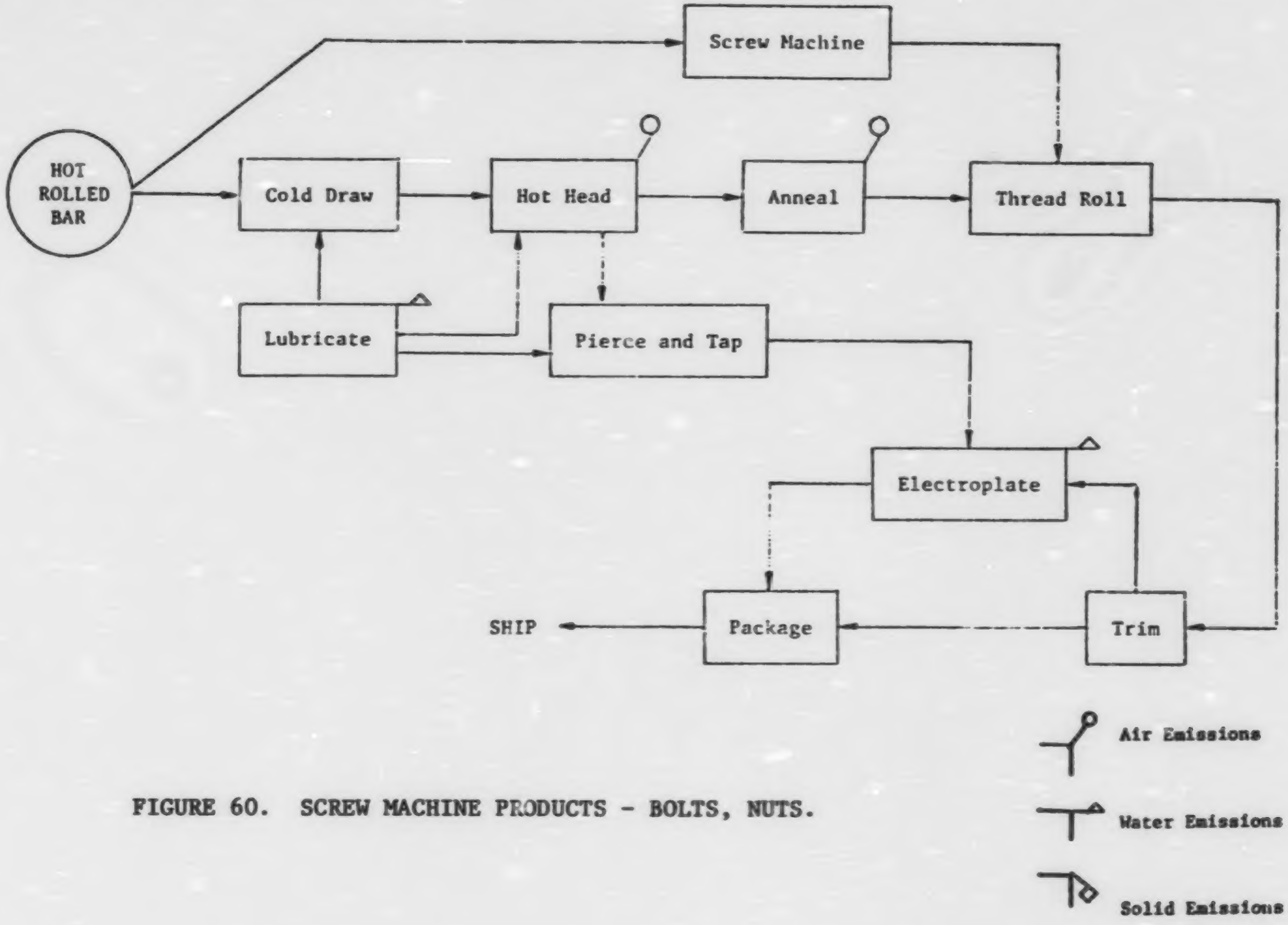
HOT ROLLED BAR
Screw Machine
Cold Draw
Hot Head
Anneal
Thread Roll
Lubricate
Pierce and Tap
Electroplate
Package
Trim
SHIP
Air Emissions
Water Emissions
Solid Emissions

FIGURE 60. SCREW MACHINE PRODUCTS - BOLTS, NUTS.

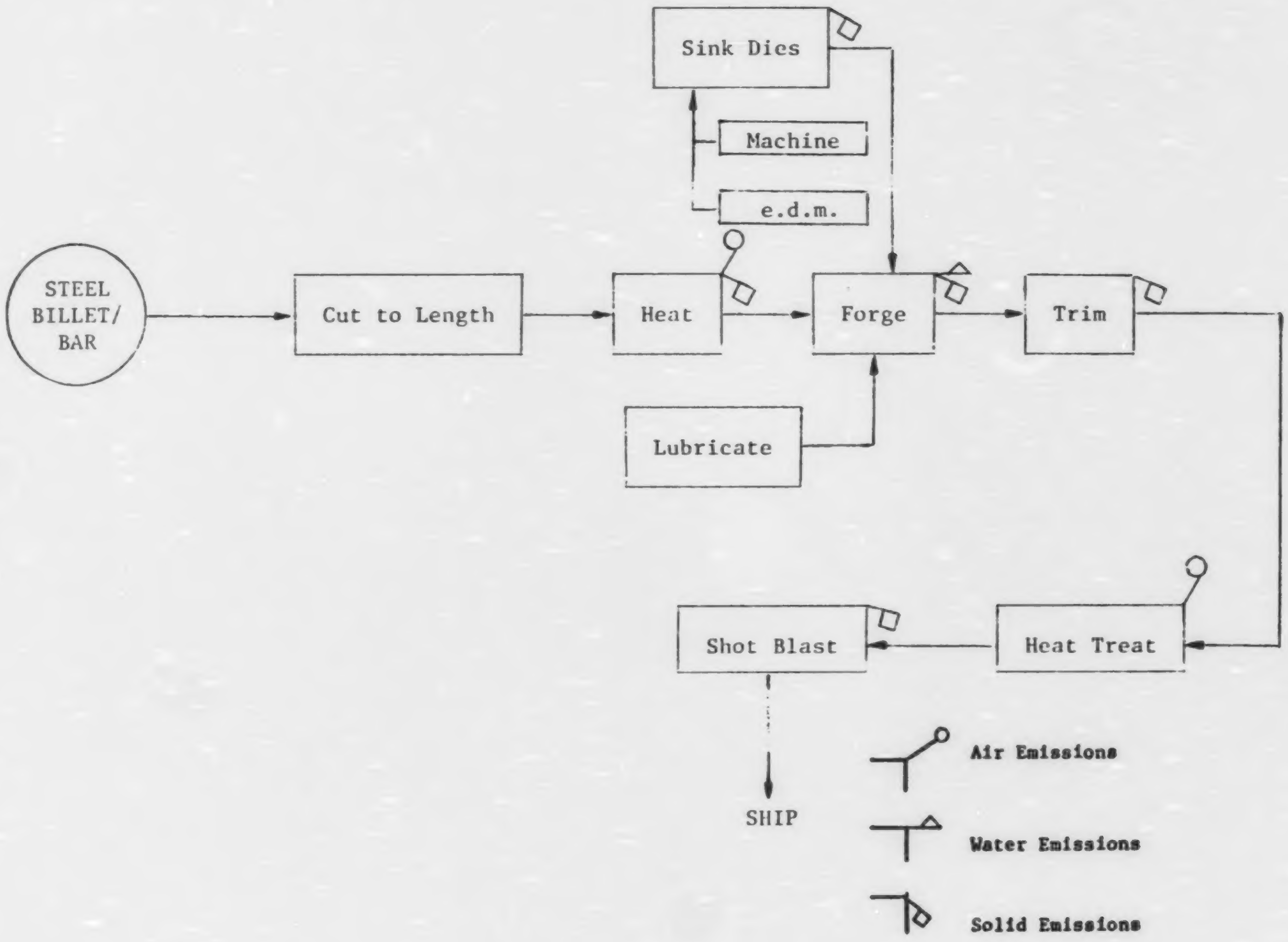
STEEL BILLET/ BAR
Cut to Length
Heat
Forge
Trim
Sink Dies
Machine
e.d.m.
Lubricate
Heat Treat
Shot Blast
SHIP
Air Emissions
Water Emissions
Solid Emissions

FIGURE 61. STEEL FORGINGS.

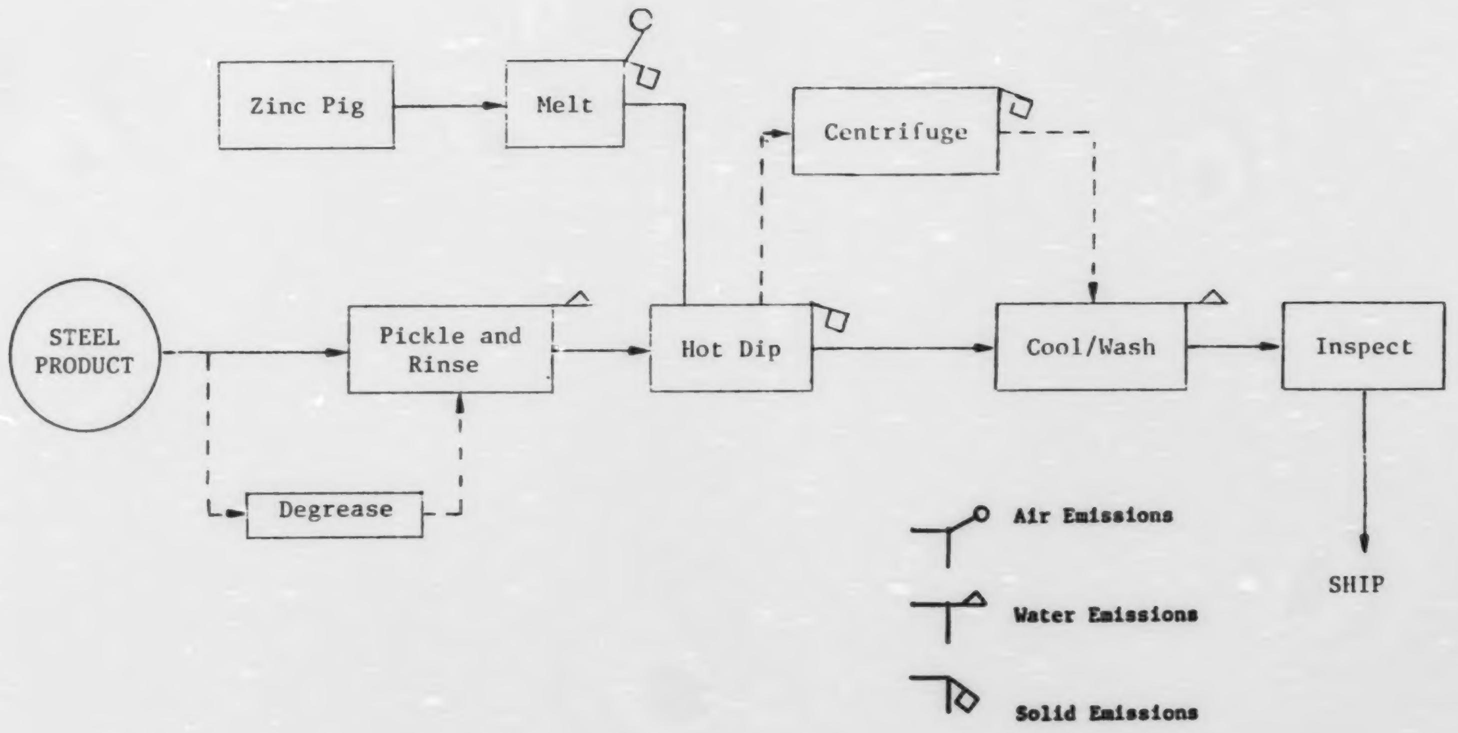
Zinc Pig
Melt
Centrifuge
STEEL PRODUCT
Pickle and Rinse
Hot Dip
Cool/Wash
Inspect
Degrease
SHIP
Air Emissions
Water Emissions
Solid Emissions

FIGURE 62. GALVANIZING FOR THE TRADE.

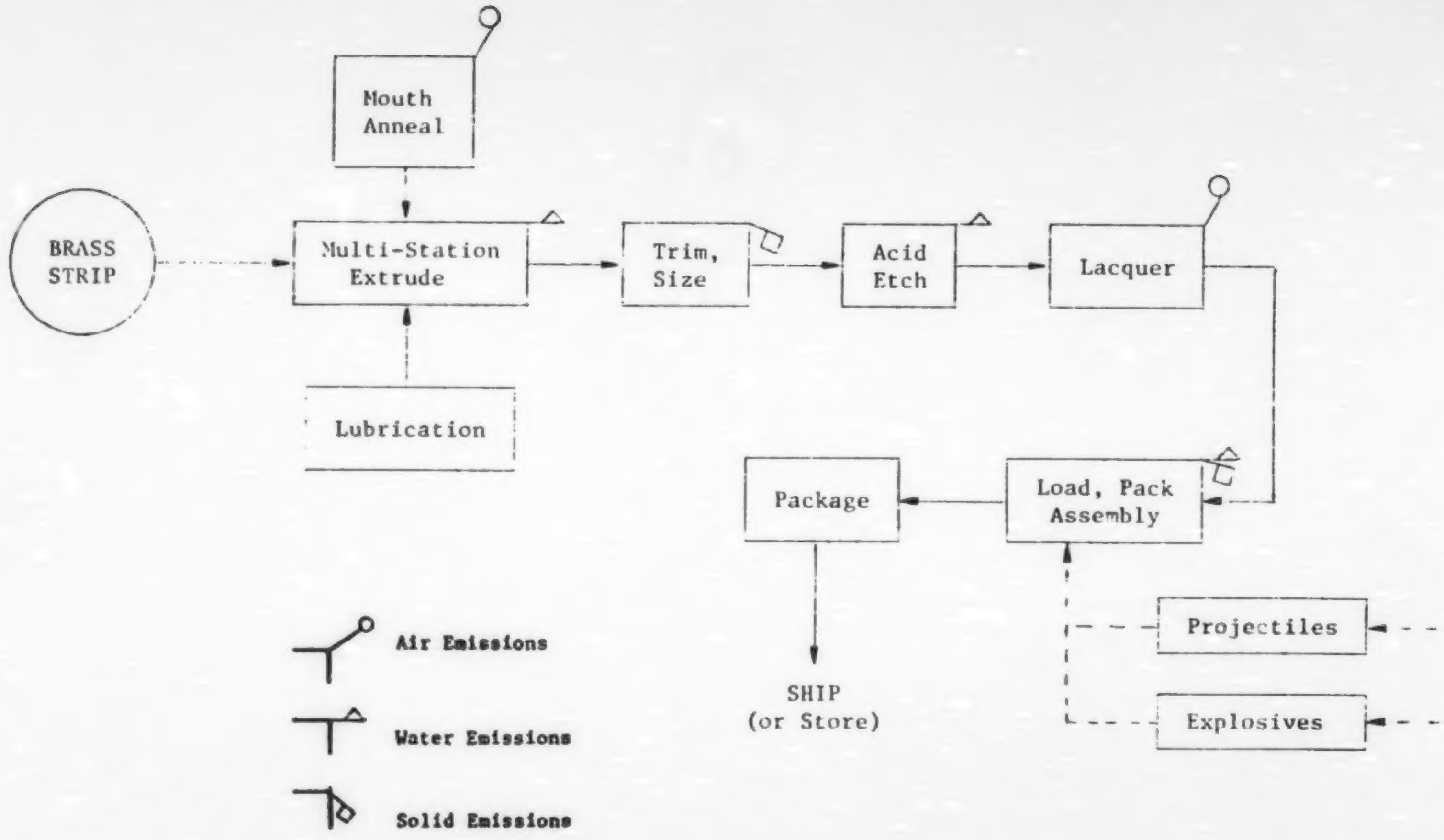
BRASS STRIP
Mouth Anneal
Multi-Station Extrude
Lubrication
Trim, Size
Acid Etch
Lacquer
Load, Pack Assembly
Package
SHIP (or Store)
Projectiles
Explosives
Air Emissions
Water Emissions
Solid Emissions

FIGURE 63. CARTRIDGE CASES.

TABLE 6. RELATIVE LEVELS OF POLLUTION INTENSITIES FOR PROCESSES TYPICALLY ASSOCIATED WITH MANUFACTURE OF FABRICATED METAL PRODUCTS.

Manufacturing Process	Pollution Intensity			
	Air	Water	Solid	Noise
Melting of metals	H/G	L/G	M/G	H/G
Casting (mold making)	H/G	M/G	M/G	M/L
Welding (stick electrode)	H/L	L/L	L/G	
Metalworking				
Forging	L/G	M/G	H/G	H/L,M/G
Rolling	L/G	L/G	H/G	M/G
Extrusion	L/G	L/G	L/G	M/G
Rollforming/ spinning	L/G	L/G	L/G	M/G
Machining	L/G	L/G	L/L	L/L
Stamping/shearing	L/G	L/G	L/G	H/L,M/G
Lubricating	H/G	H/G	M/G	-
Thermal treatments				
Heating for hot work	M/G	L/G	L/G	H/G
Annealing	L/G	L/G	L/G	M/L
Heat treatment	L/G	L/G	L/G	M/G
Baking/Drying	M/G	L/G	L/G	L/G
Brazing	M/G	M/G	L/G	L/G
Surface treatment				
Sand blasting(open air)	H/L	L/G	H/G	M/L
Polishing	L/L	M/G	M/G	M/L
Pickling/rinsing	L/G	H/G	M/G	L/L
Surface coating				
Electroplating	M/G	H/G	L/G	L/L
Painting/varnishing	M/G	M/G	M/G	L/G
Enameling	L/G	L/G	M/G	L/G
Bonderizing	L/G	H/G	L/G	L/G
Galvanizing	L/G	M/G	M/G	L/G

Code: H - High
M - Medium
L - Low

G - General Pollution in Plant
L - Local Pollution within work area of employee

local to the immediate area in which a given operation is performed. This table provides guidance regarding the general level of emphasis which would be required to reduce the pollution levels. The processes rating high/general in terms of the intensity of pollution require first attention. However, this comment relates more to the general level rather than to a diagnostic appraisal of the kinds of compounds making up the pollutants. Careful measurement and analysis would be required to determine the toxicity levels of each material passing into the waste streams. Such measurements are beyond the scope of this study.

Several tables are included that elaborate on the flow charts that were shown earlier. These tables show the unit operations, the wastes and the media in which they occur, the potential levels of pollution (low, medium or high), and actions that are currently taken to alleviate pollution. Tables illustrating these elements are shown for the following types of fabricated metal products:

Metal cans, containers
Cutlery, hand tools, hardware
Plumbing fixtures
Structural metal products
Screw machine products
Forgings and stampings
Coatings, engravings
Ordance and accessories.

MACHINERY EXCEPT ELECTRICAL

This major grouping includes establishments engaged in manufacturing machinery and equipment other than electrical equipment and transportation equipment. Machines powered by built-in or detachable motors ordinarily are included in this major grouping with the exception of electrical household appliances. Portable tools, both electrical and pneumatic powered, are included in this group, but hand tools are classified elsewhere.

This group of manufacturing firms often starts with fabricated metal products as part of the raw materials used in building the machinery. The majority of companies in this category depend heavily on suppliers of castings,forgings, screw machine products, tubing, rolled sheet and plate, wire and other semifinished products which are then machined for eventual assembly into the machines. On the other hand, these manufacturing firms utilize a wide variety of manufacturing processes as related to the assembly of subcomponents and components.

There were 40,309 establishments, which employed 1,819,700 people and shipped primary products valued at $65.6075 billion in 1972 in this major industry category.(1)

The segments of the machinery industry included in this analysis consist of the following categories:

- Engines and turbines

TABLE 7. MATERIALS AND PROCESS DATA FOR METAL CANS, CONTAINERS.

Operations[a]	Waste/Media	Potential Levels of Pollution	Current Action
Stamping	--	--	--
Roll form/welding	--	--	--
Drawing	--	--	--
Spinning	--	--	--
Acid pickling	Spent liquor/water	Medium	Neutralizing
Electroplating	Spent liquor/water	Medium	Neutralizing
Tinning	Fumes/air	Low	Venting
Galvanizing	Fumes/air	Low	Venting
Annealing	Fumes/air	Low	--
Lubricating	HC fumes/air(b)	Low	--
Lubricating	Oil/water	Medium	Skimming
Painting	HC fumes/air(b)	Medium	Venting
Baking	Fumes/air	Low	Venting
Welding	Fumes/air	Medium/local	Venting

(a) The following raw materials are used in these operations: sheet steel, sheet aluminum, lubricants, paints, tin pig/electrodes, zinc, and acids.

(b) HC = hydrocarbon

TABLE 8. MATERIALS AND PROCESS DATA FOR CUTLERY, HAND TOOLS, HARDWARE.

Operations (a)	**Waste/Media**	**Potential Levels of Pollution**	**Current Action**
Casting	Fumes/air	Medium to high	--
Forging	Lubricants/air,water	Low	--
Stamping	Lubricants/air,water	Low	--
Welding	Fumes/air	Medium/local	--
Sanding	Dust/air	Low	--
Electroplating	Spent liquor/water	Medium	Neutralizing
Machining	--	--	--
Annealing	Fumes/air	Low	--
Heat treating	Fumes/air	Low	--
Lubricating	Fumes/air	Low	--
--	Oil/water	Medium	Oil separators
Painting	HC fumes (b)	Low	--
Baking	Fumes	Low	Venting
Acid pickling	Spent liquor/water		Neutralizing

(a) The following raw materials are used in these operations: Bar steel, castings, sheet steel, forgings, wire, paint, acids, and sands.

(b) HC = hydrocarbon.

TABLE 9. MATERIALS AND PROCESS DATA FOR PLUMBING FIXTURES.

Operations[a]	**Waste/Media**	**Potential Levels of Pollution**	**Current Action**
Casting	Fumes/air	Medium	Venting
Forging	--	--	--
Machining	--	--	--
Electroplating	Spent liquor/water	Medium	Neutralize
Baking	Fumes/air	Low	--
Heat treating	Fumes/air	Low	--
Enameling	Fumes/air	Low	--
Tube forming	--	--	--
Die casting	Fumes/air	Low	Venting
Lubricating(process)	Oils/water	Medium	
Blanking	--	--	--
Welding	Fumes/air	Medium/local	Venting
Brazing	Fumes/air	Low	Venting

(a) The following raw materials are used in these operations: steel scrap, iron scrap pig, brass, zinc, rubber, and plastics.

TABLE 10. MATERIALS AND PROCESS DATA FOR FABRICATED STRUCTURAL METAL PRODUCTS.

Operations[a]	**Waste/Media**	**Potential Levels of Pollution**	**Current Action**
Welding	Fumes/air	Medium/local	--
Riveting	--	--	--
Forming	--	--	--
Forging	--	--	--
Heat treating	Fumes/air	Low	--
Torch cutting	Fumes/air	Medium/local	Venting
Drilling	--	--	--
Galvanizing	--	--	--
Annealing	Fumes/air	Low	--
Painting	Fumes/air	Medium	--
Preheating	--	--	--
Lubrication	Oil/water	Low	--

(a) The following raw materials are used in these operations: steel plate, structurals, sheet aluminum, extrusions, roll-formed shapes, rebar, and paints.

TABLE 11. MATERIALS AND PROCESS DATA FOR SCREW MACHINE PRODUCTS.

Operations	**Waste/Media**	**Potential Levels of Pollution**	**Current Action**
Machining	--	--	--
Cold forging	Stearate soaps/water	Medium	--
Stamping	--	--	--
Lubricating	Oil/water	Low	--
Electroplating	Liquors/water	Low	--
Pickling	Liquors/water	Low	--

(a) The following raw materials are used in these operations: wire, sheet steel, plastic tubing, steel bar, and copper bar.

TABLE 12. MATERIALS AND PROCESS DATA FOR METAL FORGINGS AND STAMPINGS.

Operations [(a)]	Waste/Media	Potential Levels of Pollution	Current Action
Forging	--	--	--
Stamping	--	--	--
Shearing	--	--	--
Punching	--	--	--
Bending	--	--	--
Rolling	--	--	--
Spinning	--	--	--
Welding	Fumes/air	Low	--
Machining	--	--	--
Galvanizing	Fumes/air	Low	--
Painting	Fumes/air (HC)[(b)]	Medium	Venting
Baking	Fumes/air	Medium	--
Tinning	Fumes/air	Low	--
Heating	Fumes/air	Medium	--
Annealing	Fumes/air	Low	--
Heat treating	Fumes/air	Low	--
Lubricating	Fumes/air Oils/water	Medium/local Medium	-- Cascade separation
Sand blasting	--	--	--
Polishing	--	--	--

(a) The following raw materials are used in these operations: steel billet, steel bar, die steels, nonferrous billet, nonferrous bar, stainless steel, steel sheet/plate, glass frits, lubricants, and paints.

(b) HC = hydrocarbon.

TABLE 13. MATERIALS AND PROCESS DATA FOR COATINGS, ENGRAVINGS, (SERVICES).

Operations[a]	**Waste/Media**	**Potential Levels of Pollution**	**Current Action**
Acid etching	Spent acids/water	Medium	Neutralizing
Anodizing	Spent acids/water	Medium	Neutralizing
Painting	Vapors/air	Low	--
Tinning	Vapors/air	Low	--
Galvanizing	Vapors/air	Low	--
Polishing	Dust/air	Medium/local	--
Electroplating	Acids/water	Low	Neutralizing

(a) The following raw materials are used in these operations: chromium, nickel, copper, precious metals, soaps, paints/varnishes, hydrocarbon coatings, aluminum pig, zinc pig, and tin pig.

TABLE 14. MATERIALS AND PROCESS DATA FOR ORDANCE AND ACCESSORIES.

Operations	Waste/Media	Potential Levels of Pollution	Current Action
Extrusion	--	--	--
Forging	Scale/solids	Medium	--
Drawing	--	--	--
Stamping	--	--	--
Casting	Fumes-dust/air	Medium	Precipitators
Rolling	--	--	--
Swaging	Scale/solids	--	--
Machinery	--	--	--
Lubricating	Fumes/air oil/water	Low Medium	-- Separation
Sand blasting	Dust/solid	Low	--
Painting	Fumes/air	Medium	Electrostatic
Baking	Fumes/air	Low	Venting
Heat treating	--	--	--
Annealing	--	--	--
Load/pack	Dust/air	Medium	--

(a) The following raw materials are used in these operations: brass strip, steel strip, acids, pig iron, bar/billet, paint (HC), lubricants, explosives, paper, wood, caustics, (tool steels), hydraulic fluids (HC)(b), plastics, sands, binders (HC)(b), and quenching oils.

(b) HC - hydrocarbon.

- Farm and garden machinery and equipment
- Construction, mining and handling machinery and equipment
- Metalworking machinery and equipment
- Special and general industrial machinery and equipment
- Office, computing, and accounting machines
- Refrigeration and service industry machinery.

Engines and Turbines

Companies in this group are primarily engaged in the manufacture of steam turbines; hydraulic turbines; gas turbines (except aircraft); steam, gas, and hydraulic turbine generator units; steam engines; and internal combustion engines. Establishments in this industrial grouping generally do not have an integrated operation involving the manufacture of such basic raw materials as castings, forgings, bar stock, rolled structurals, extrusions, etc. Such items are ordinarily purchased for subsequent fabrication into components and subcomponents. On the other hand, industrial firms in this grouping have extensive machine tools for machining, blanking, shearing, drilling, simple forming, welding, and assembling of the final products. There are exceptions. For example, two of the leading producers of outboard motors have their own in-house capability for casting certain components including motor blocks, pistons, and heads.

Manufacturing Processes--

In general internal combustion engines are made by drilling, tapping, and machining a cast block to accept other machined components such as cylinder wall linings, pistons and connecting rods, crankshafts and valve assemblies.(37) A flow diagram is given in Figure 64 showing some of the steps involved in manufacturing small to medium internal combustion engines.

Waste Streams--

Other than the casting operations and the local pollution associated with welding, this industrial grouping is not associated with a serious impact on the environment. Most of the scrap steel and nonferrous materials used by this industry group are recycled.

Farm and Garden Machinery and Equipment

This segment includes establishments primarily engaged in manufacturing farm and garden machinery and equipment such as wheel tractors, agricultural weeding machines, lawn mowers, and garden tractors. Some of the larger companies in this industry also produce castings, forgings, stampings, and many other fabricated metal products.

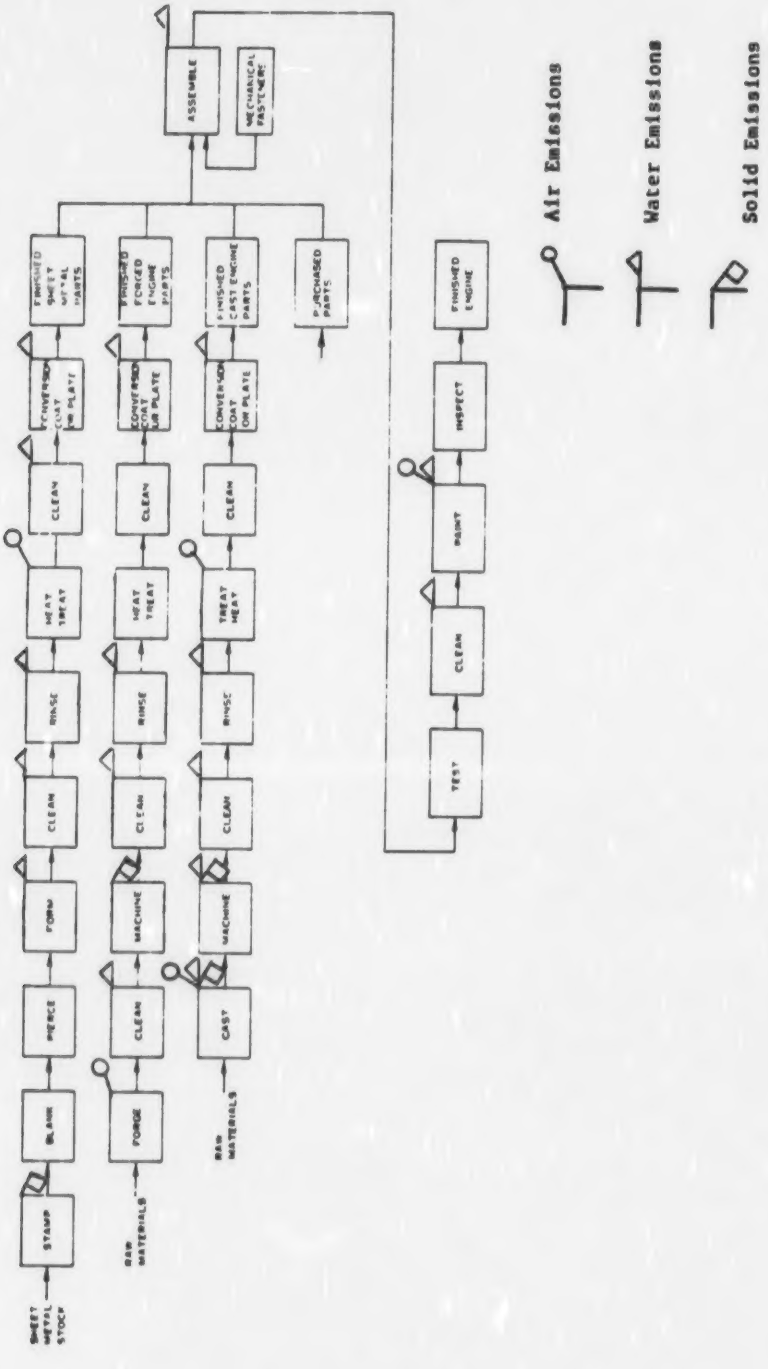
SHEET METAL STOCK
STAMP
BLANK
PIERCE
FORM
CLEAN
RINSE
HEAT TREAT
CLEAN
CONVERSION COAT OR PLATE
FINISHED SHEET METAL PARTS
RAW MATERIALS
FORGE
CLEAN
MACHINE
CLEAN
RINSE
HEAT TREAT
CLEAN
CONVERSION COAT OR PLATE
FINISHED FORGED ENGINE PARTS
RAW MATERIALS
CAST
MACHINE
CLEAN
RINSE
TREAT HEAT
CLEAN
CONVERSION COAT OR PLATE
FINISHED CAST ENGINE PARTS
PURCHASED PARTS
ASSEMBLE
MECHANICAL FASTENERS
TEST
CLEAN
PAINT
INSPECT
FINISHED ENGINE
Air Emissions
Water Emissions
Solid Emissions

FIGURE 64. INTERNAL COMBUSTION ENGINES.

Manufacturing Processes--(37)

Farm tractors and attachments are fabricated from a variety of piece parts including major purchased parts (motor, transmission, seats, gages, etc.) and parts manufactured by the industry (frame, axles, housings, covers, etc.). A typical operation for manufacturing farm machinery is shown in Figure 65.

Manufacture of garden and lawn equipment includes cutting, bending, and welding the frame and mounting the engine, wheels, handles, and trim to this frame. All components are generally painted except for gears, bearings and sprockets which are heat treated to improve wear characteristics. A typical operation in the manufacture of a snowblower is shown in Figure 66.

Waste Streams--

Painting and welding operations seem to be the dominating factors in the development of pollution from this grouping. The relative volume of scrap turnings and trimmings is usually high enough to encourage recycling to the mill suppliers of the metals or to scrap dealers.

Construction, Mining and Handling Machinery and Equipment

This industry grouping produces heavy machinery and equipment used largely by the construction, mining, drilling, and other manufacturing industries. The products are often one of a kind requiring extensive machining and welding operations. Some of the companies have their own foundries for manufacturing heavy components. However, the majority of companies purchase forgings, castings, and other structural materials from companies manufacturing fabricated metal products.

Manufacturing Processes--(37)

In contrast to the companies involved with the manufacture of passenger automobiles, the companies in this grouping are not usually associated with highly automated assembly lines. The manufacture of bulldozers can be considered as reasonably typical, including some hot forming, extensive shearing and cutting, welding, and mechanical fastening followed by painting and final assembly. A simplified flow diagram for the manufacture of bulldozers is presented in Figure 67.

Flow diagrams are also shown for the production of the following products in this industry grouping to illustrate the wide diversity of manufacturing operations associated with this classification of industries:

Products	Figure Number
Underground scraper/loaders	68
Rock bits	69
Derricks	70

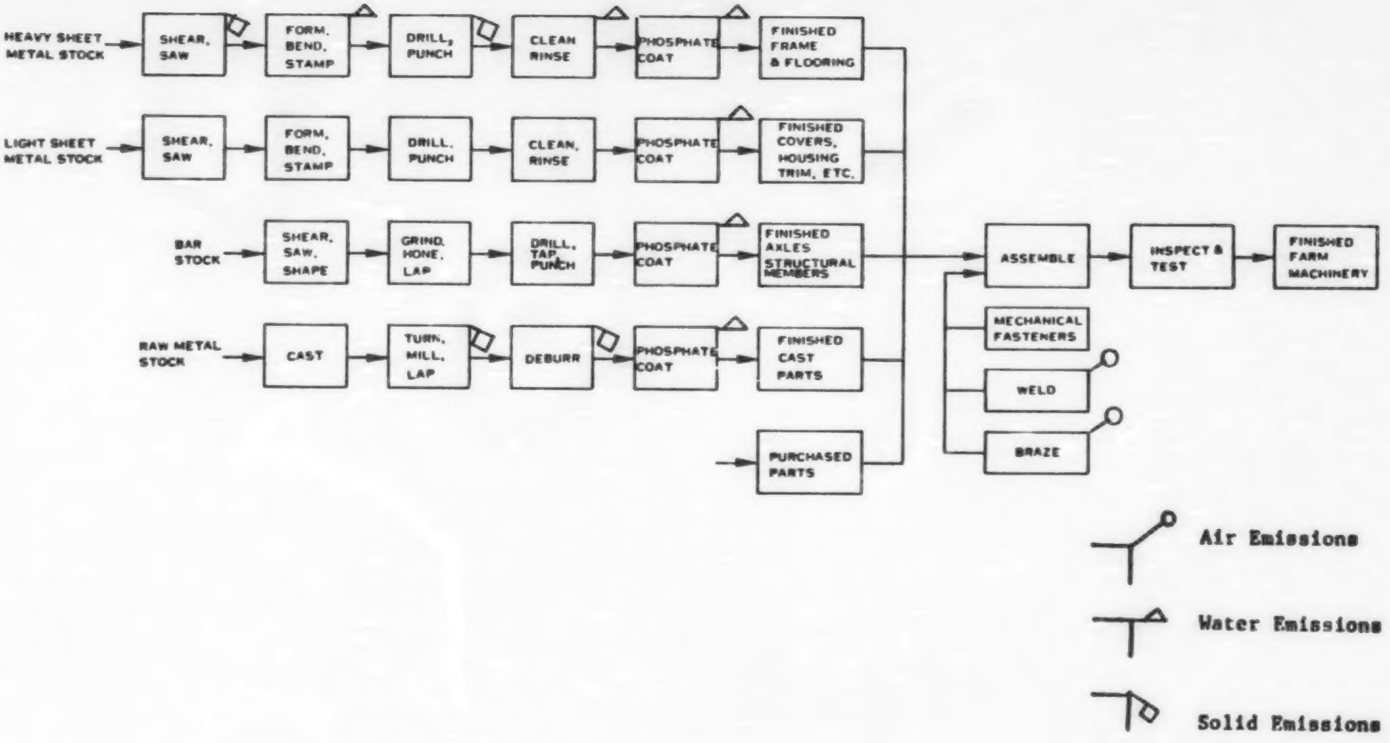
HEAVY SHEET METAL STOCK
SHEAR, SAW
FORM, BEND, STAMP
DRILL, PUNCH
CLEAN RINSE
PHOSPHATE COAT
FINISHED FRAME & FLOORING
LIGHT SHEET METAL STOCK
SHEAR, SAW
FORM, BEND, STAMP
DRILL, PUNCH
CLEAN, RINSE
PHOSPHATE COAT
FINISHED COVERS, HOUSING TRIM, ETC.
BAR STOCK
SHEAR, SAW, SHAPE
GRIND, HONE, LAP
DRILL, TAP, PUNCH
PHOSPHATE COAT
FINISHED AXLES STRUCTURAL MEMBERS
RAW METAL STOCK
CAST
TURN, MILL, LAP
DEBURR
PHOSPHATE COAT
FINISHED CAST PARTS
PURCHASED PARTS
ASSEMBLE
MECHANICAL FASTENERS
WELD
BRAZE
INSPECT & TEST
FINISHED FARM MACHINERY
Air Emissions
Water Emissions
Solid Emissions

FIGURE 65. FARM MACHINERY.

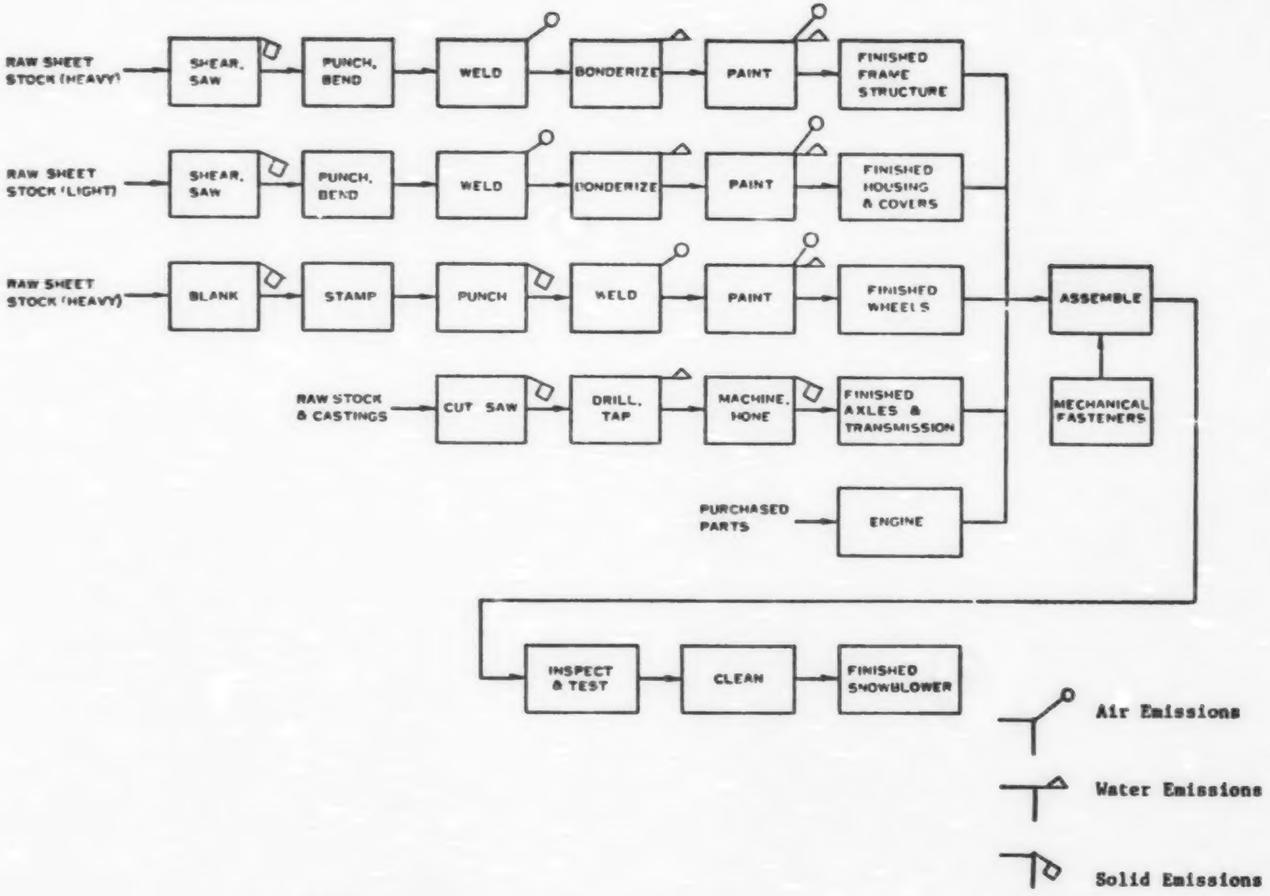
RAW SHEET STOCK (HEAVY)
SHEAR, SAW
PUNCH, BEND
WELD
BONDERIZE
PAINT
FINISHED FRAME STRUCTURE
RAW SHEET STOCK (LIGHT)
SHEAR, SAW
PUNCH, BEND
WELD
BONDERIZE
PAINT
FINISHED HOUSING & COVERS
RAW SHEET STOCK (HEAVY)
BLANK
STAMP
PUNCH
WELD
PAINT
FINISHED WHEELS
RAW STOCK & CASTINGS
CUT SAW
DRILL, TAP
MACHINE, HONE
FINISHED AXLES & TRANSMISSION
PURCHASED PARTS
ENGINE
ASSEMBLE
MECHANICAL FASTENERS
INSPECT & TEST
CLEAN
FINISHED SNOWBLOWER
Air Emissions
Water Emissions
Solid Emissions

FIGURE 66. MANUFACTURE OF SNOWBLOWER.

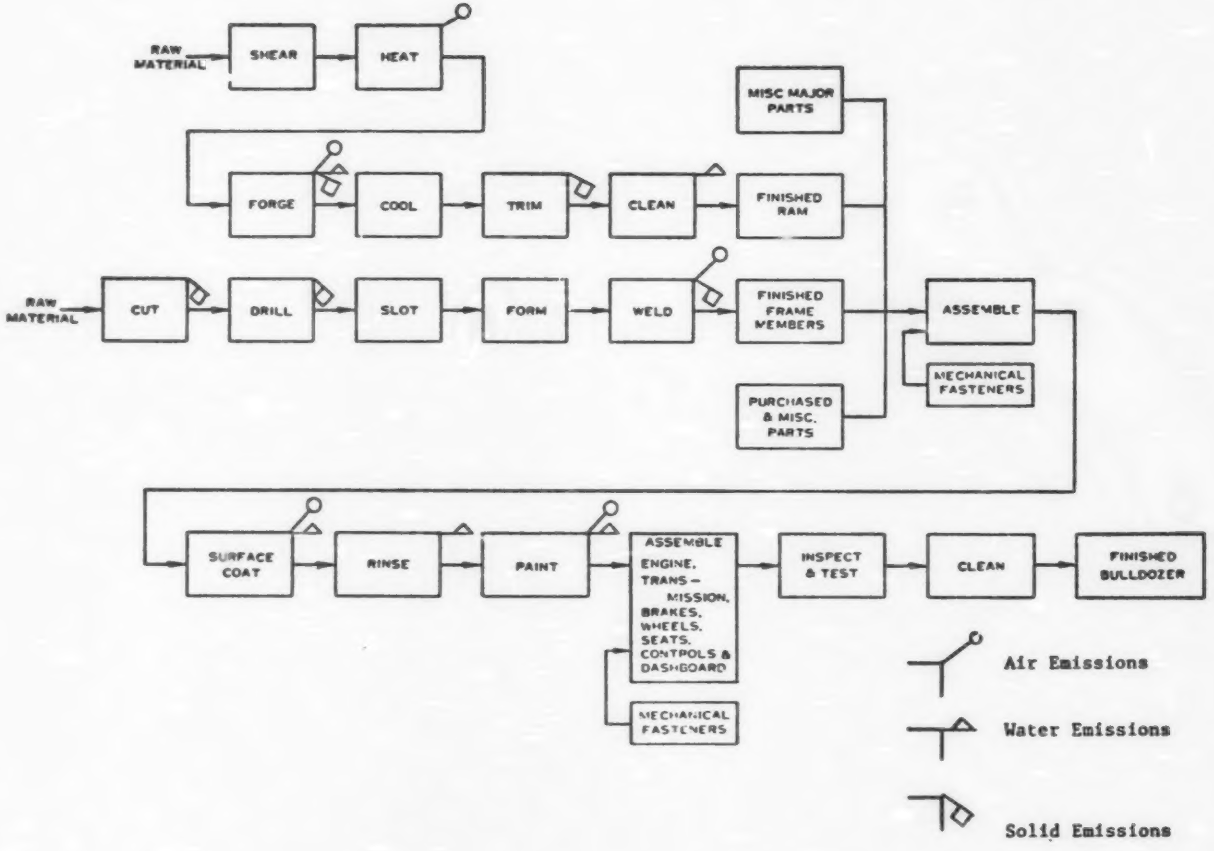
RAW MATERIAL
SHEAR
HEAT
FORGE
COOL
TRIM
CLEAN
FINISHED RAM
MISC MAJOR PARTS
RAW MATERIAL
CUT
DRILL
SLOT
FORM
WELD
FINISHED FRAME MEMBERS
PURCHASED & MISC. PARTS
ASSEMBLE
MECHANICAL FASTENERS
SURFACE COAT
RINSE
PAINT
ASSEMBLE ENGINE, TRANS-MISSION, BRAKES, WHEELS, SEATS, CONTPOLS & DASHBOARD
MECHANICAL FASTENERS
INSPECT & TEST
CLEAN
FINISHED BULLDOZER
Air Emissions
Water Emissions
Solid Emissions

FIGURE 67. MANUFACTURE OF BULLDOZERS.

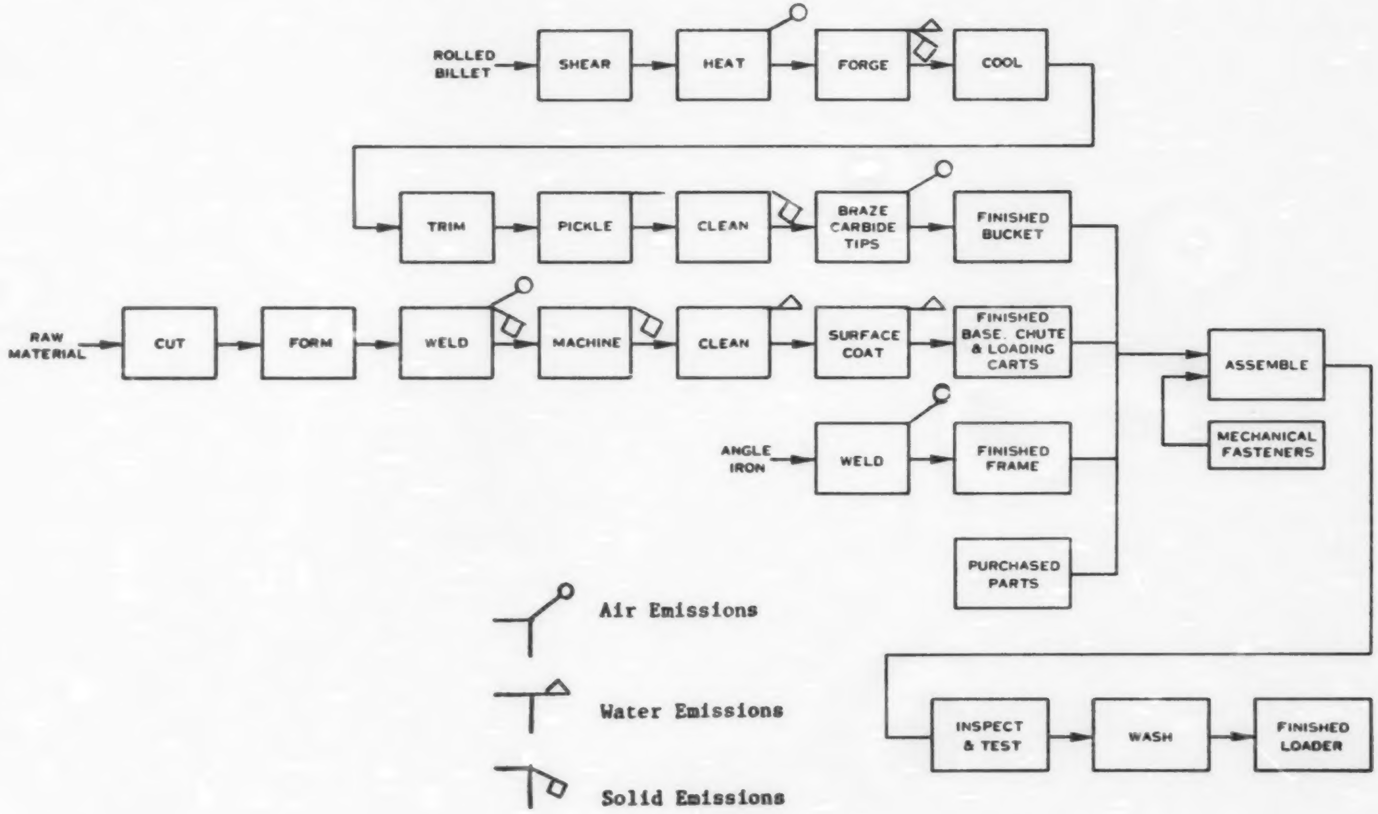
ROLLED BILLET
SHEAR
HEAT
FORGE
COOL
TRIM
PICKLE
CLEAN
BRAZE CARBIDE TIPS
FINISHED BUCKET
RAW MATERIAL
CUT
FORM
WELD
MACHINE
CLEAN
SURFACE COAT
FINISHED BASE, CHUTE & LOADING CARTS
ANGLE IRON
WELD
FINISHED FRAME
PURCHASED PARTS
ASSEMBLE
MECHANICAL FASTENERS
INSPECT & TEST
WASH
FINISHED LOADER
Air Emissions
Water Emissions
Solid Emissions

FIGURE 68. MANUFACTURE OF UNDERGROUND SCRAPER/LOADERS.

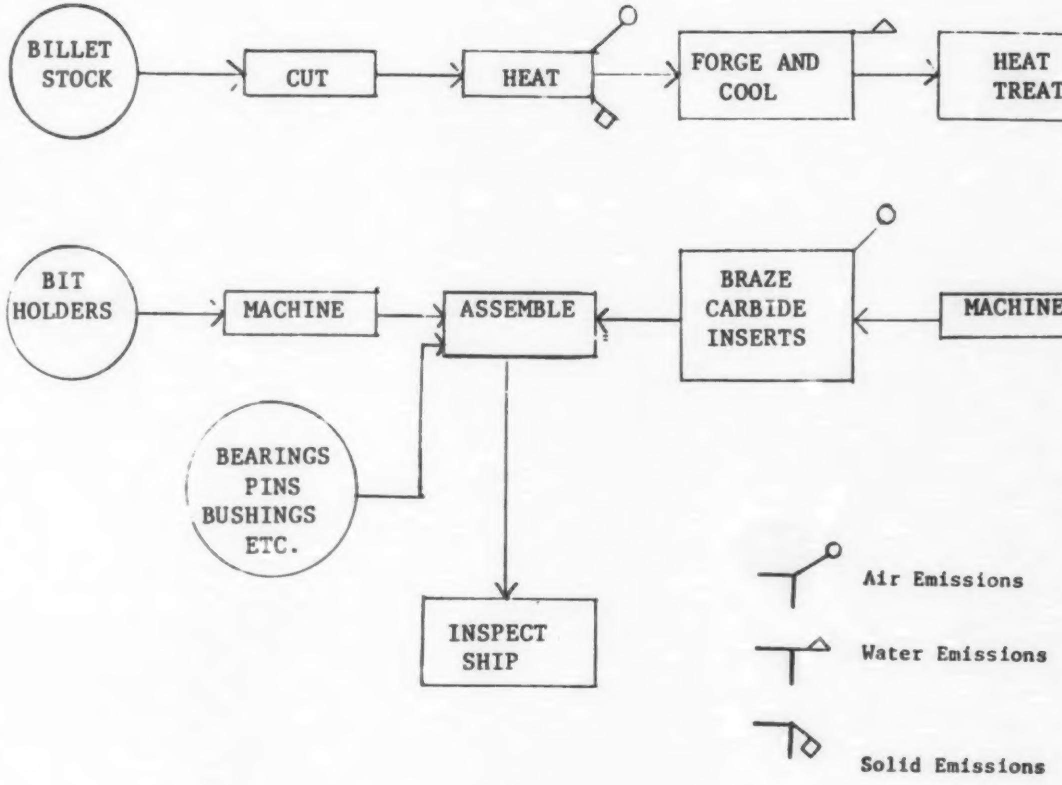
BILLET STOCK
CUT
HEAT
FORGE AND COOL
HEAT TREAT
BIT HOLDERS
MACHINE
ASSEMBLE
BRAZE CARBIDE INSERTS
MACHINE
BEARINGS PINS BUSHINGS ETC.
INSPECT SHIP
Air Emissions
Water Emissions
Solid Emissions

FIGURE 69. MANUFACTURE OF ROCK BITS.

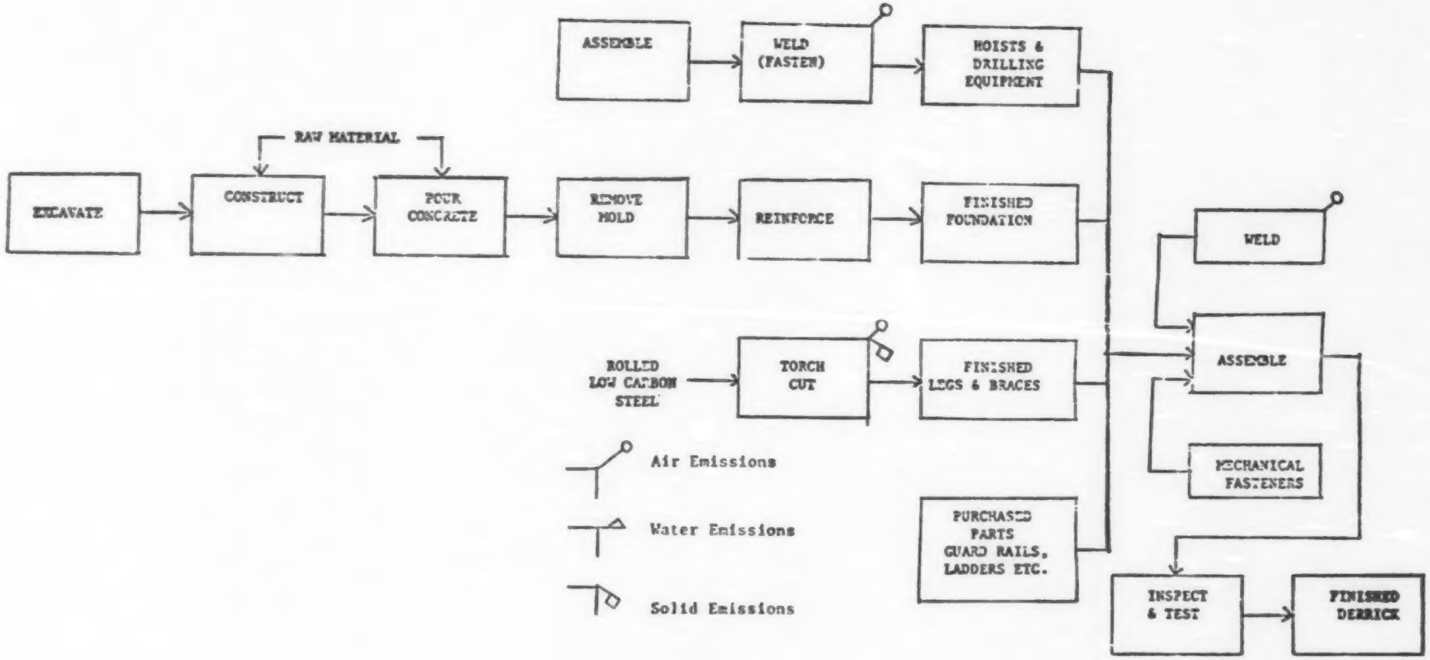
ASSEMBLE
WELD (FASTEN)
HOISTS & DRILLING EQUIPMENT
RAW MATERIAL
EXCAVATE
CONSTRUCT
POUR CONCRETE
REMOVE MOLD
REINFORCE
FINISHED FOUNDATION
WELD
ROLLED LOW CARBON STEEL
TORCH CUT
FINISHED LEGS & BRACES
ASSEMBLE
MECHANICAL FASTENERS
PURCHASED PARTS GUARD RAILS, LADDERS ETC.
INSPECT & TEST
FINISHED DERRICK
Air Emissions
Water Emissions
Solid Emissions

FIGURE 70. MANUFACTURE OF DERRICKS.

Waste Streams--

The processes having the greatest impact on the environment are the casting, welding, flame cutting, machining, and painting operations. Oils are used in the metal forming operations and to lubricate the various assembly operations.

Metalworking Machinery and Equipment

Companies involved in the manufacture of machine tools (laths, boring mills, drill presses, etc.), metal-forming equipment (presses, hammers, shears, heading machines, etc.), and other types of equipment for tooling and machining, stamping, forging, extrusion, grinding, hot rolling, drilling, etc., are typically integrated back to the machining and assembly operations for manufacturing their products, and few of the companies actually produce forgings or castings for their own use. Since the advent of foundry emission controls, some of those companies which, in fact, had their own foundries have since closed them because of the relatively higher cost of operation and new capital equipment required. Erie Foundry is a good example. This company is a leader in the manufacture of hot-forming presses and formerly cast many of its press components. The foundry now operates only on a very limited basis and the company now purchases many of its castings from commercial sources.

Manufacturing Processes--(37)

Generally, metal-forming machine tools are made by forming, machining, and welding plates into a specific machine configuration. These plates are then assembled along with associated accessories and the final product painted. Figures 71 and 72 show flow diagrams for an engine lathe and electrochemical machine respectively.

Generally, machine tool accessories are made by machining the part to shape from forgings, castings, bar stock, or plate. Parts are then ground and polished to obtain the desired size and finish and are finally heat treated. Figure 73 shows a flow diagram for manufacturing drill bits.

Waste Streams--

The main sources of waste products from companies in this general industrial area are associated with the metal-forming, machining, and assembly operation. The machining operations result in large quantities of turnings which are almost always stored and eventually resold as scrap. Welding operations, grinding, and machining and the associated cutting oils and painting operations represent the chief sources for pollutants. Flame scarfing and torch cutting are also practiced extensively and are associated with high levels of smoke and dust.

It should be noted that this grouping of industries is an extensive user of such subassemblies as motor bearings, vacuum pumps, hydraulic pumps, gears, and transmissions which are more often produced by companies in other industrial groupings.

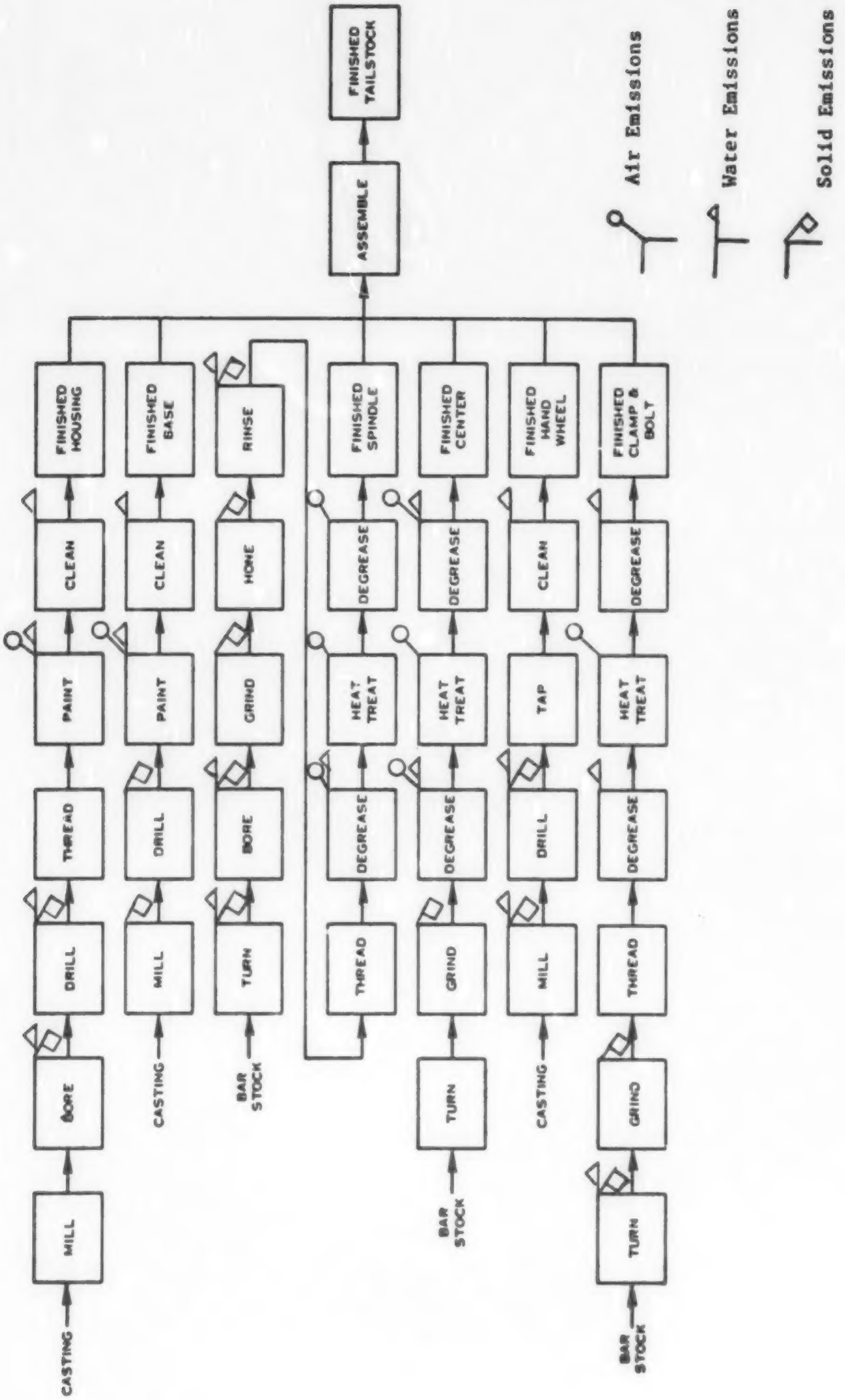
CASTING
MILL
BORE
DRILL
THREAD
PAINT
CLEAN
FINISHED HOUSING
CASTING
MILL
DRILL
PAINT
CLEAN
FINISHED BASE
BAR STOCK
TURN
BORE
GRIND
HONE
RINSE
THREAD
DEGREASE
HEAT TREAT
DEGREASE
FINISHED SPINDLE
BAR STOCK
TURN
GRIND
DEGREASE
HEAT TREAT
DEGREASE
FINISHED CENTER
CASTING
MILL
DRILL
TAP
CLEAN
FINISHED HAND WHEEL
BAR STOCK
TURN
GRIND
THREAD
DEGREASE
HEAT TREAT
DEGREASE
FINISHED CLAMP & BOLT
ASSEMBLE
FINISHED TAILSTOCK
Air Emissions
Water Emissions
Solid Emissions

FIGURE 71. ENGINE LATHE (TAILSTOCK) MANUFACTURING.

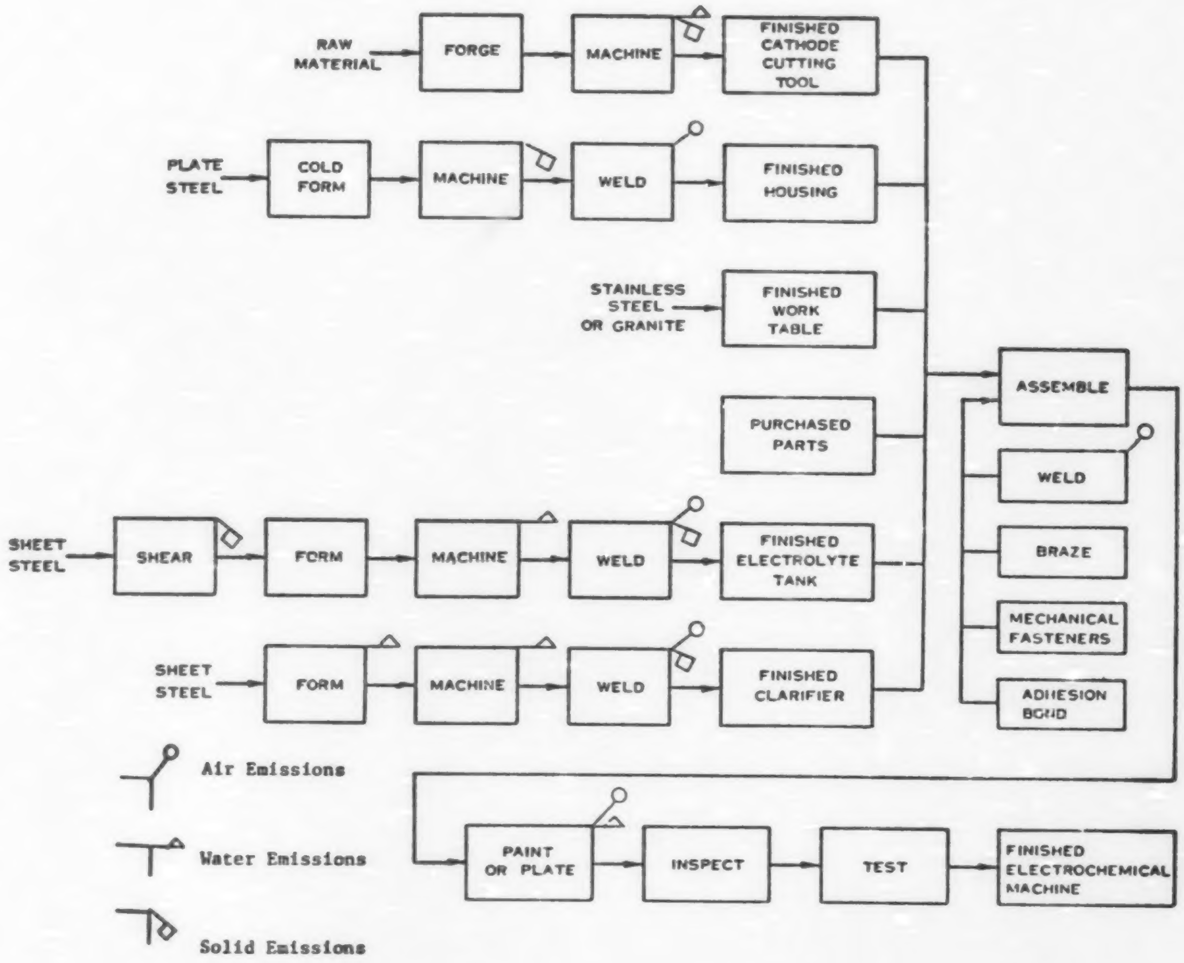
RAW MATERIAL
FORGE
MACHINE
FINISHED CATHODE CUTTING TOOL
PLATE STEEL
COLD FORM
MACHINE
WELD
FINISHED HOUSING
STAINLESS STEEL OR GRANITE
FINISHED WORK TABLE
PURCHASED PARTS
SHEET STEEL
SHEAR
FORM
MACHINE
WELD
FINISHED ELECTROLYTE TANK
SHEET STEEL
FORM
MACHINE
WELD
FINISHED CLARIFIER
ASSEMBLE
WELD
BRAZE
MECHANICAL FASTENERS
ADHESION BOND
PAINT OR PLATE
INSPECT
TEST
FINISHED ELECTROCHEMICAL MACHINE
Air Emissions
Water Emissions
Solid Emissions

FIGURE 72. ECM (ELECTROCHEMICAL MACHINE) MANUFACTURING.

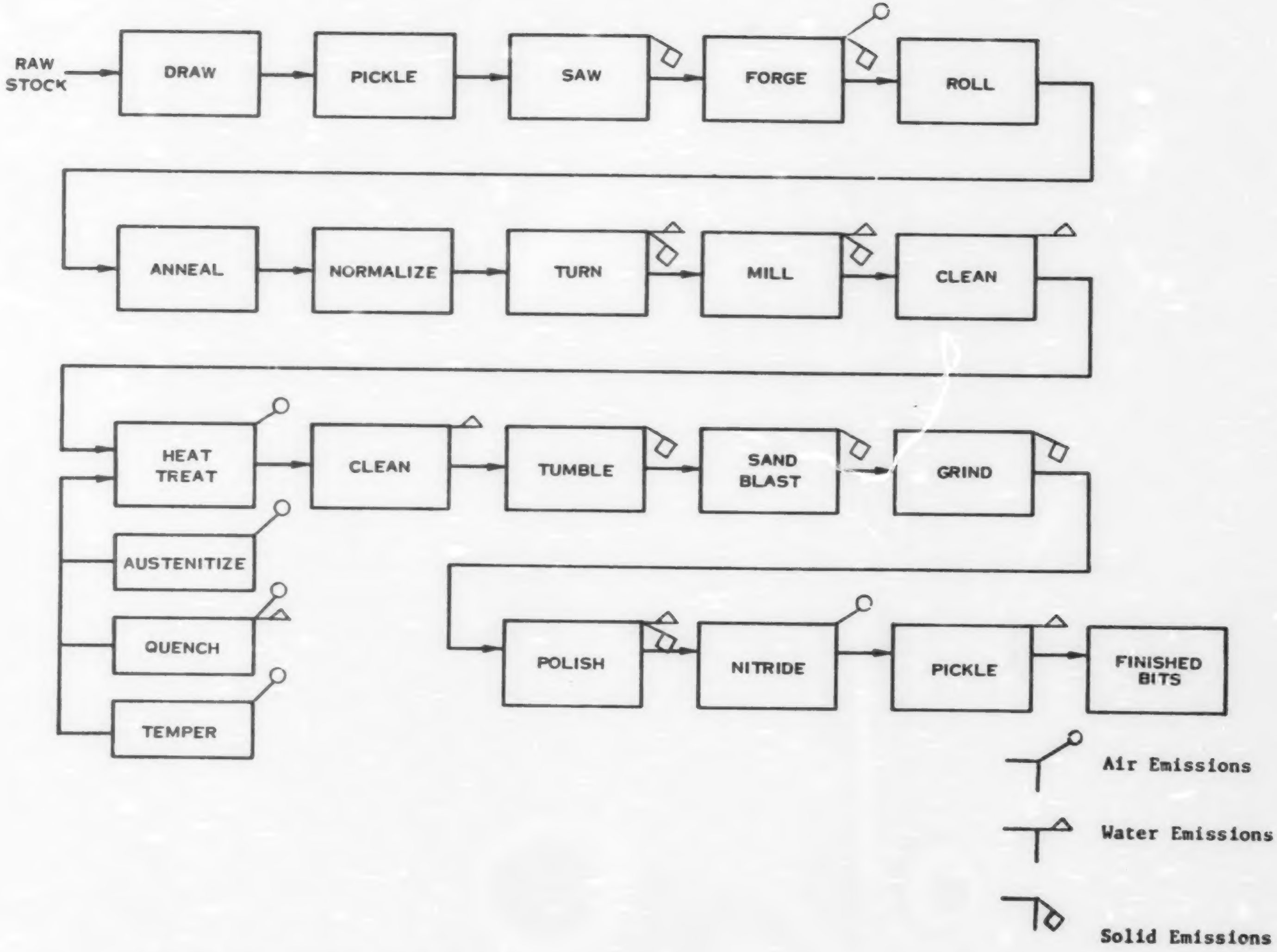
RAW STOCK
DRAW
PICKLE
SAW
FORGE
ROLL
ANNEAL
NORMALIZE
TURN
MILL
CLEAN
HEAT TREAT
AUSTENITIZE
QUENCH
TEMPER
CLEAN
TUMBLE
SAND BLAST
GRIND
POLISH
NITRIDE
PICKLE
FINISHED BITS
Air Emissions
Water Emissions
Solid Emissions

FIGURE 73. METAL WORKING DRILL BITS MANUFACTURING.

Special and General Industrial Machinery and Equipment

This rather broad grouping of industries produces products ranging from food processing devices to patterns for casting and from printing equipment to packaging machinery. In many respects the manufacturing operations are similar to those used in the manufacture of metalworking machinery and equipment. The materials differ somewhat in that much more stainless steel is used for food processing and for the printing machinery. Because this category also includes many types of small hand-operated machines, there is a wider use of wood and plastic for handles, levers, wood patterns, etc.

Manufacturing Processes (37)--

General manufacturing processes are described for the following industries: food products machinery, textile machinery, pumps and compressors, ball and roller bearings, industrial patterns, and furnaces and ovens.

Food products machinery is made by assembling manufactured and purchased parts. Since contamination is a serious concern in the food products industry, stainless steel, unit construction, and manufacturing parts for quick and easy disassembly and cleaning are used. Figure 74 shows a diagram for manufacturing pasteurizing machinery.

Textile machinery is produced by assembling assorted manufactured and purchased parts. In general, moving parts are machined, heat treated, and finished to close tolerances. Figure 75 shows a flow diagram for manufacturing a knitting machine.

Pumps and compressors are produced by casting and machining housing and pistons, hobbing gears, forging and machining crankshafts, and making or purchasing all other essential parts. Figure 76 shows a flow diagram for making a simple hydraulic gear pump.

Ball and roller bearings are produced in four parallel line operations, one for each of the bearing elements (two race balls, balls, and retainers). The races are machined and ground, the balls are formed in a die and the retainers are blanked, pierced, and formed. Not all bearing manufacturers produce their own rolling elements and, for some roller bearings, the retainers may be purchased. Figure 77 shows a flow diagram for manufacturing ball bearings.

Industrial patterns are produced by making a clay mockup for visualization. Then precision formed (by machining and bench hand tooling) wooden patterns are made to establish the shape on experimental or limited production castings. When in production, a metallized pattern is usually cast from the master. Figure 78 shows a flow diagram for pattern manufacturing.

Furnaces and ovens are made by fastening together heavy formed plates by welding and riveting. The interior is then lined with durable nonflammable material. Then the entire outer surface of the furnace is painted. Figure 79 shows a flow diagram for manufacturing a Heroult type direct-arc electric

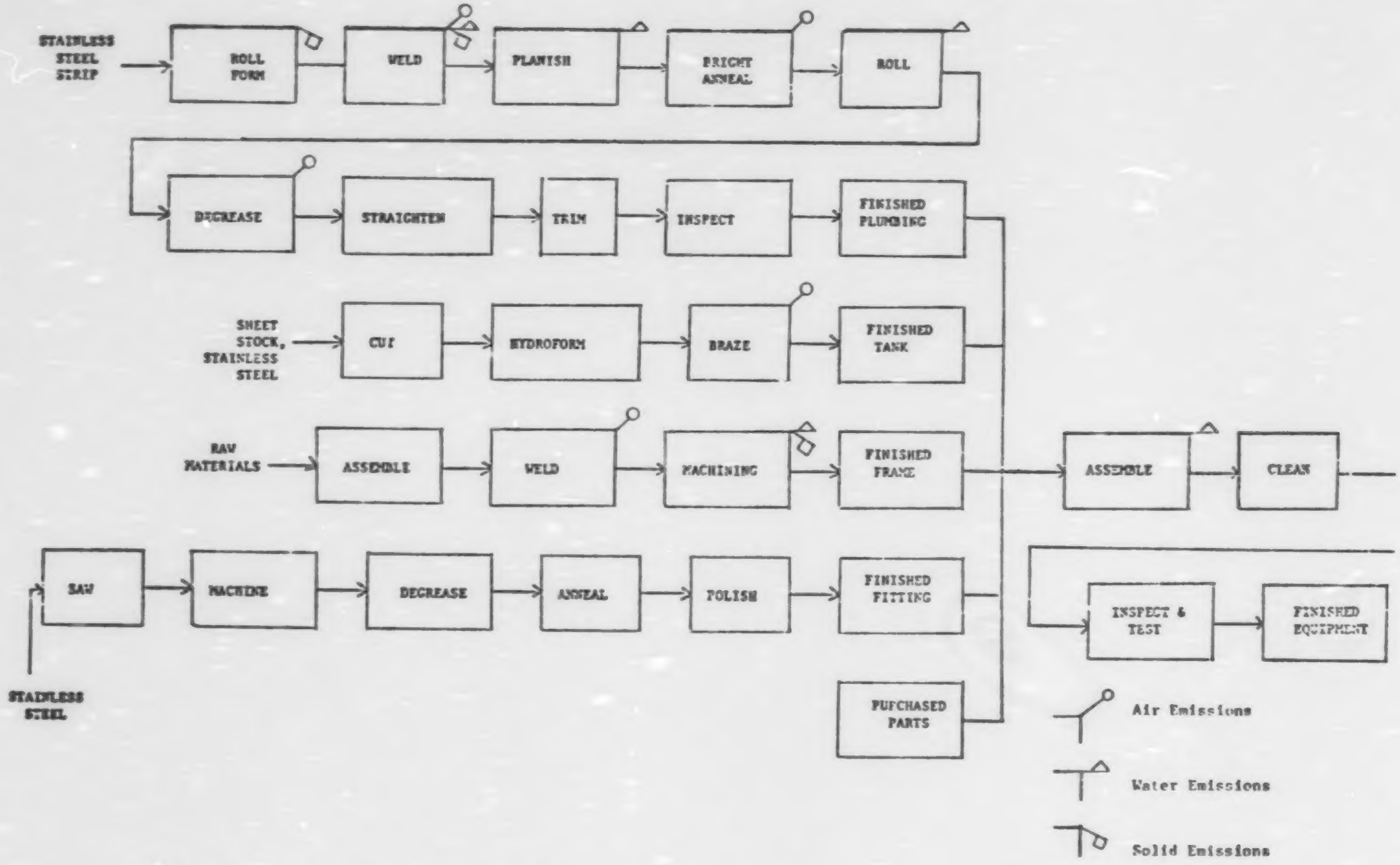
STAINLESS STEEL STRIP
ROLL FORM
WELD
PLANISH
BRIGHT ANNEAL
ROLL
DEGREASE
STRAIGHTEN
TRIM
INSPECT
FINISHED PLUMBING
SHEET STOCK, STAINLESS STEEL
CUT
HYDROFORM
BRAZE
FINISHED TANK
RAW MATERIALS
ASSEMBLE
WELD
MACHINING
FINISHED FRAME
ASSEMBLE
CLEAN
SAW
MACHINE
DEGREASE
ANNEAL
POLISH
FINISHED FITTING
INSPECT & TEST
FINISHED EQUIPMENT
STAINLESS STEEL
PURCHASED PARTS
Air Emissions
Water Emissions
Solid Emissions

FIGURE 74. PASTEURIZING EQUIPMENT MANUFACTURING.

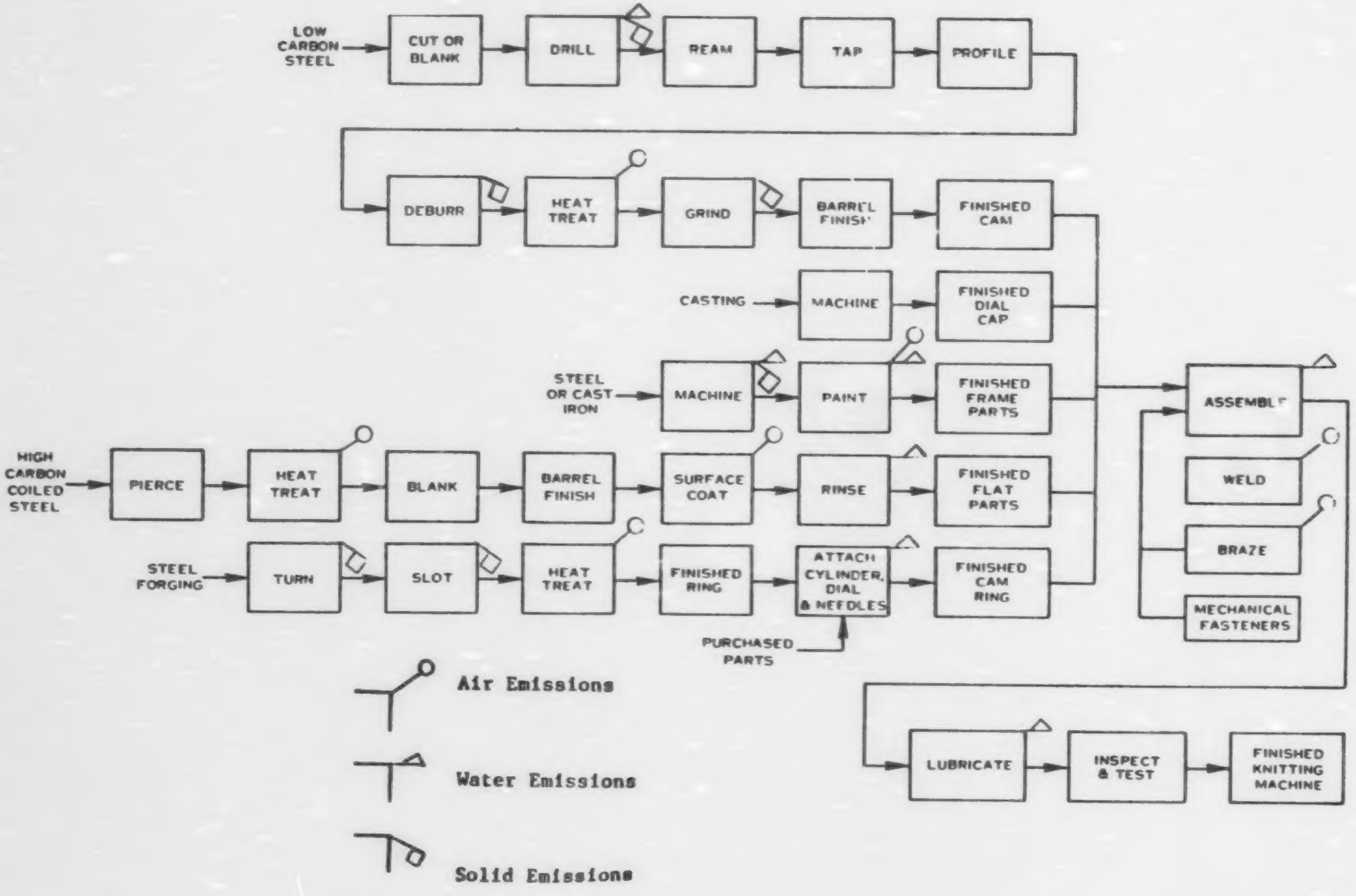
LOW CARBON STEEL
CUT OR BLANK
DRILL
REAM
TAP
PROFILE
DEBURR
HEAT TREAT
GRIND
BARREL FINISH
FINISHED CAM
CASTING
MACHINE
FINISHED DIAL CAP
STEEL OR CAST IRON
MACHINE
PAINT
FINISHED FRAME PARTS
HIGH CARBON COILED STEEL
PIERCE
HEAT TREAT
BLANK
BARREL FINISH
SURFACE COAT
RINSE
FINISHED FLAT PARTS
STEEL FORGING
TURN
SLOT
HEAT TREAT
FINISHED RING
ATTACH CYLINDER, DIAL & NEEDLES
FINISHED CAM RING
PURCHASED PARTS
ASSEMBLE
WELD
BRAZE
MECHANICAL FASTENERS
LUBRICATE
INSPECT & TEST
FINISHED KNITTING MACHINE
Air Emissions
Water Emissions
Solid Emissions

FIGURE 75. KNITTING MACHINE MANUFACTURING.

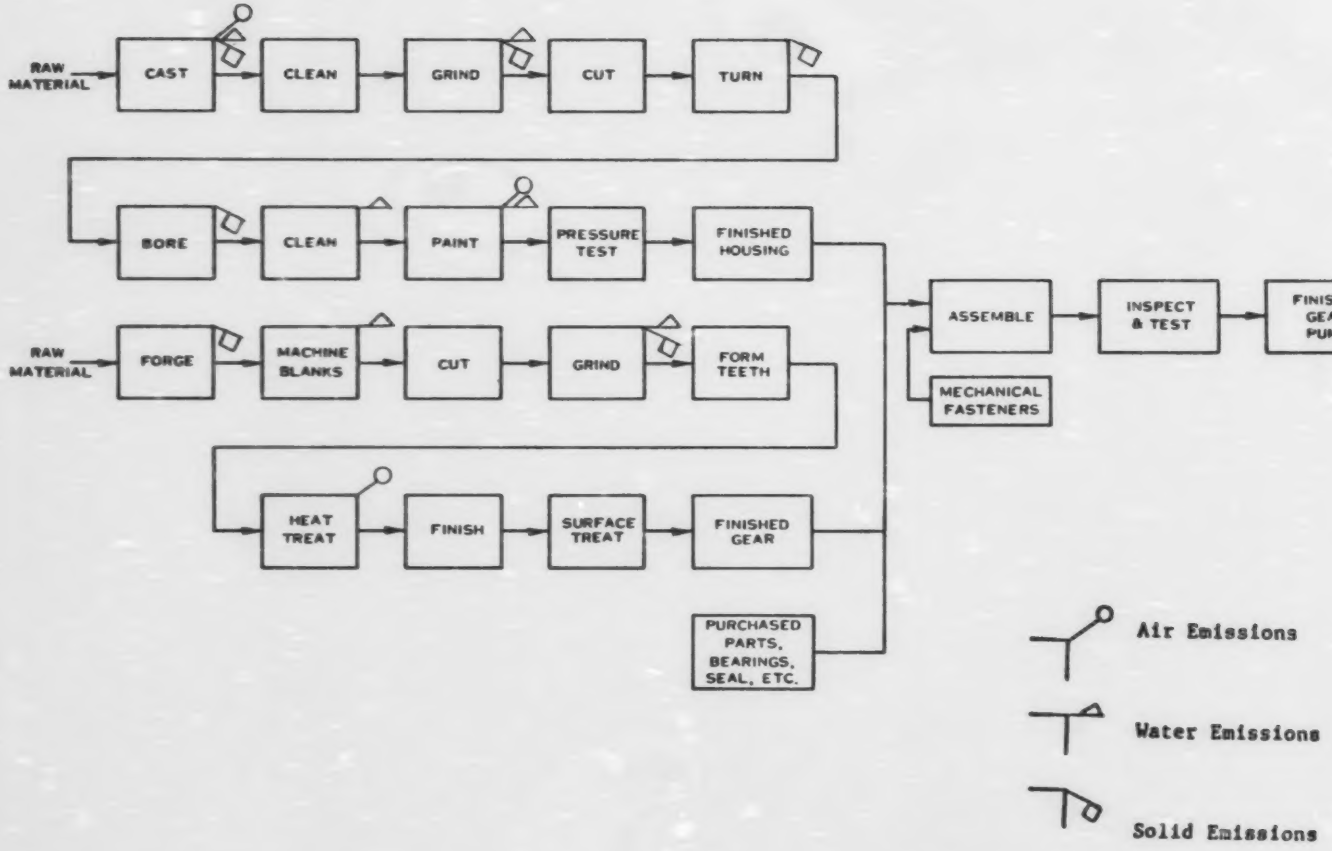
RAW MATERIAL
CAST
CLEAN
GRIND
CUT
TURN
BORE
CLEAN
PAINT
PRESSURE TEST
FINISHED HOUSING
RAW MATERIAL
FORGE
MACHINE BLANKS
CUT
GRIND
FORM TEETH
HEAT TREAT
FINISH
SURFACE TREAT
FINISHED GEAR
PURCHASED PARTS, BEARINGS, SEAL, ETC.
ASSEMBLE
MECHANICAL FASTENERS
INSPECT & TEST
FINISHED GEAR PUMP
Air Emissions
Water Emissions
Solid Emissions

FIGURE 76. HYDRAULIC GEAR PUMP MANUFACTURING.

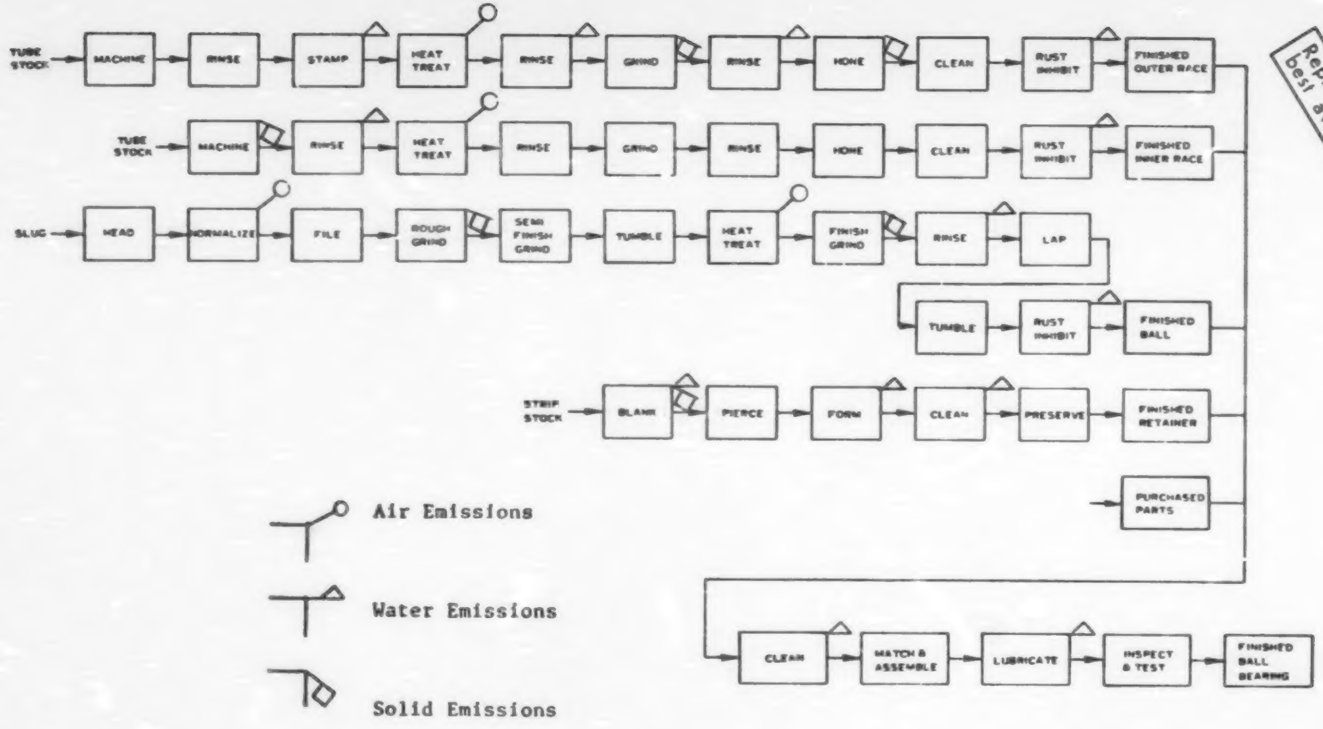
TUBE STOCK
MACHINE
RINSE
STAMP
HEAT TREAT
RINSE
GRIND
RINSE
HONE
CLEAN
RUST INHIBIT
FINISHED OUTER RACE
TUBE STOCK
MACHINE
RINSE
HEAT TREAT
RINSE
GRIND
RINSE
HONE
CLEAN
RUST INHIBIT
FINISHED INNER RACE
SLUG
HEAD
NORMALIZE
FILE
ROUGH GRIND
SEMI FINISH GRIND
TUMBLE
HEAT TREAT
FINISH GRIND
RINSE
LAP
TUMBLE
RUST INHIBIT
FINISHED BALL
STRIP STOCK
BLANK
PIERCE
FORM
CLEAN
PRESERVE
FINISHED RETAINER
PURCHASED PARTS
CLEAN
MATCH & ASSEMBLE
LUBRICATE
INSPECT & TEST
FINISHED BALL BEARING
Air Emissions
Water Emissions
Solid Emissions

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FIGURE 77. BALL BEARING MANUFACTURING.

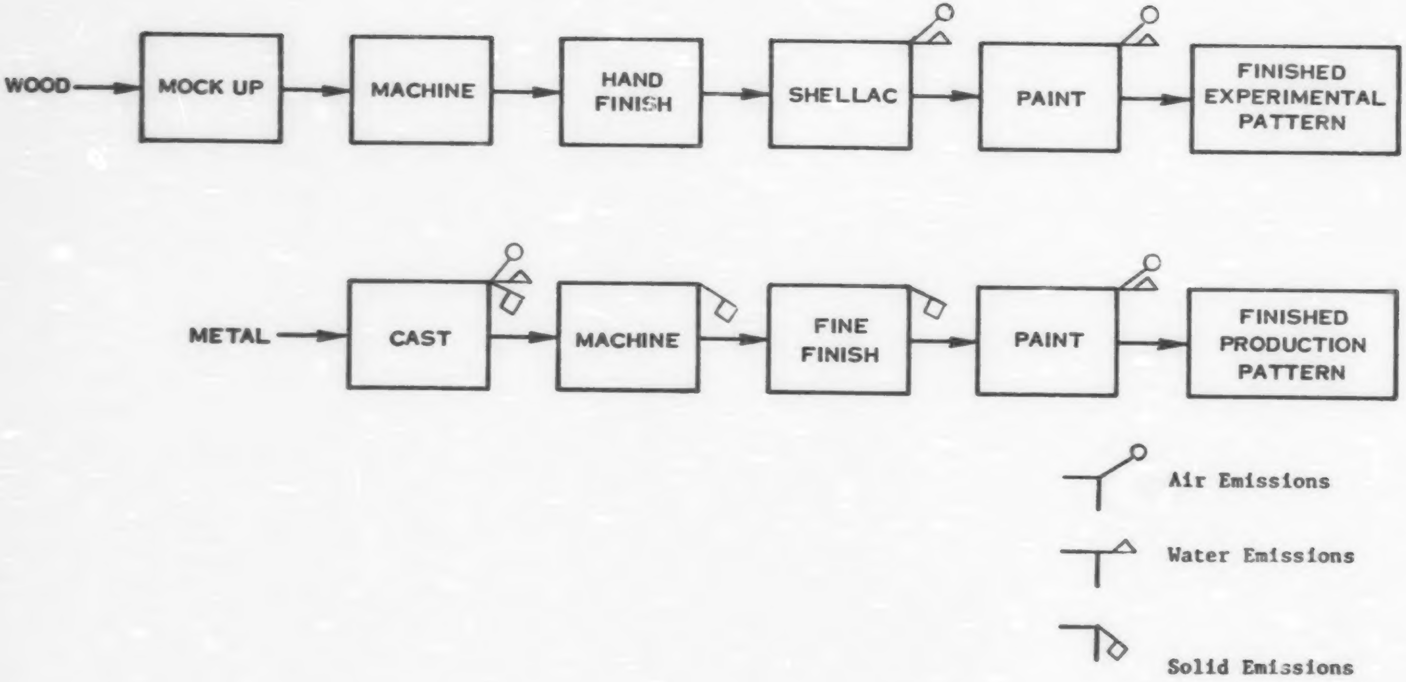
WOOD
MOCK UP
MACHINE
HAND FINISH
SHELLAC
PAINT
FINISHED EXPERIMENTAL PATTERN
METAL
CAST
MACHINE
FINE FINISH
PAINT
FINISHED PRODUCTION PATTERN
Air Emissions
Water Emissions
Solid Emissions

FIGURE 78. PATTERN MANUFACTURING.

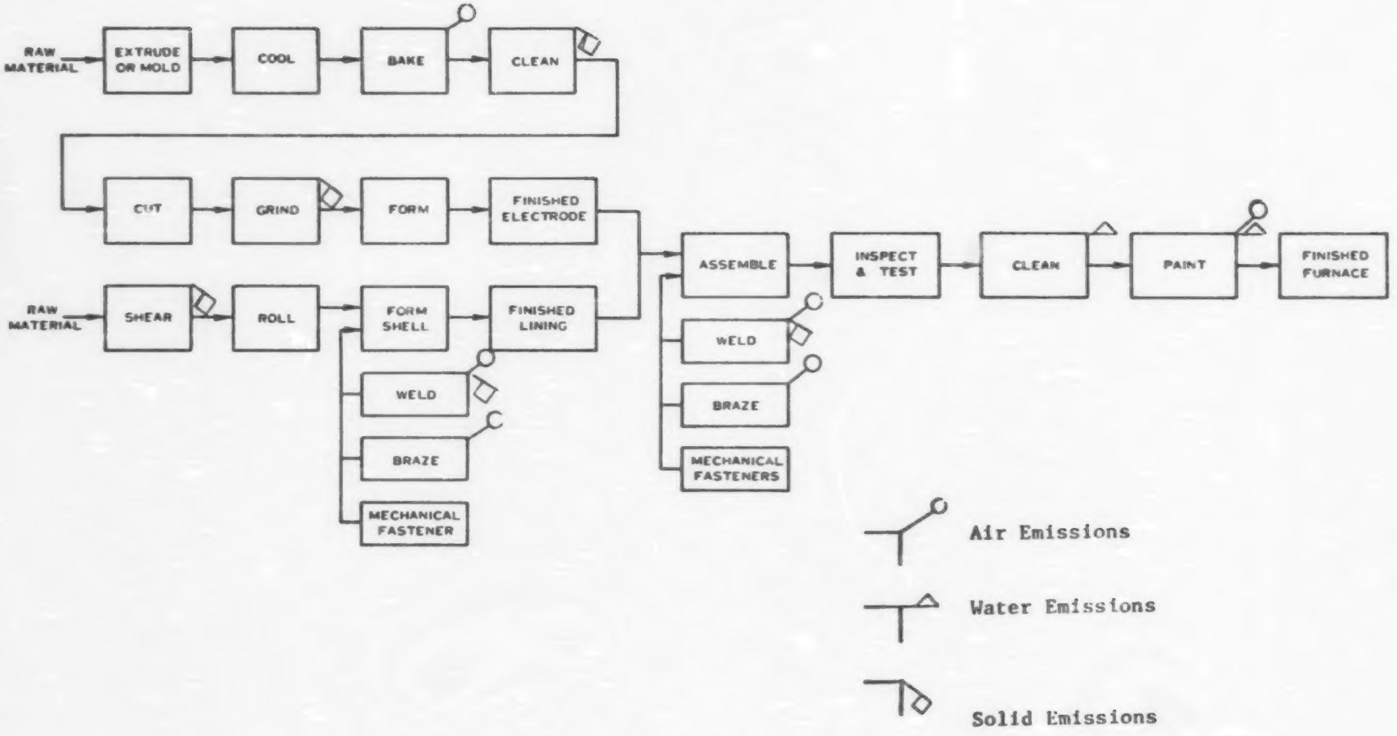
RAW MATERIAL
EXTRUDE OR MOLD
COOL
BAKE
CLEAN
CUT
GRIND
FORM
FINISHED ELECTRODE
RAW MATERIAL
SHEAR
ROLL
FORM SHELL
FINISHED LINING
WELD
BRAZE
MECHANICAL FASTENER
ASSEMBLE
WELD
BRAZE
MECHANICAL FASTENERS
INSPECT & TEST
CLEAN
PAINT
FINISHED FURNACE
Air Emissions
Water Emissions
Solid Emissions

FIGURE 79. METAL MELTING FURNACE MANUFACTURING.

furnace.

Waste Streams--

Lubricating oils are typically found associated with most of the assembly operations and usually end up in the wastewater. Acid pickling also is extensively practiced and could represent a problem if the wastewaters are not properly neutralized. The operations of welding, flame cutting, machining, assembling, metal forming, painting, cleaning, etc. are major contributors to waste products. Plastics and plastic-coated materials are likely to become part of the waste products and can result in air pollution when these materials are heated during the remelting operations by the companies which purchase scrap materials from companies in this grouping. This is more of an indirect source of waste products which do not show up until the scrap metal reaches the steel mills.

Office, Computing, and Accounting Machines

This segment includes establishments primarily engaged in manufacturing office machines and devices and typewriters. Office machines and typewriters were produced in 217 establishments, by 33,900 employees, and primary products shipped were valued at $1.2323 billion in 1972.

Manufacturing Processes (37)--

Office machines are made by sawing or shearing low-carbon steel and then forming it into a frame configuration. The machining operations for the frame and internal parts include milling, notching, turning, drilling, tapping, grinding, buffing, and tumbling. The various parts are joined by welding, soldering, riveting, and staking. Parts are then phosphated, painted, inspected, and shipped. Figure 80 shows a flow diagram for making duplicating machines.

Waste Streams--

Process water is used mainly for cleaning after machining operations for plating. Operations such as machining, buffing, drilling, and grinding contribute to the solid waste stream. Air emissions result from such operations as welding, painting, and baking.

Refrigeration and Service Industry Machinery

This segment includes establishments primarily engaged in manufacturing refrigeration equipment and systems and similar equipment for commercial and industrial use; complete air conditioning units for domestic, commercial, and industrial use; and warm air furnaces, except electric. Establishments primarily engaged in manufacturing soda fountains and beer-dispensing equipment and humidifiers and dehumidifiers, except for room humidifiers and dehumidifiers, are also classified in this industry.

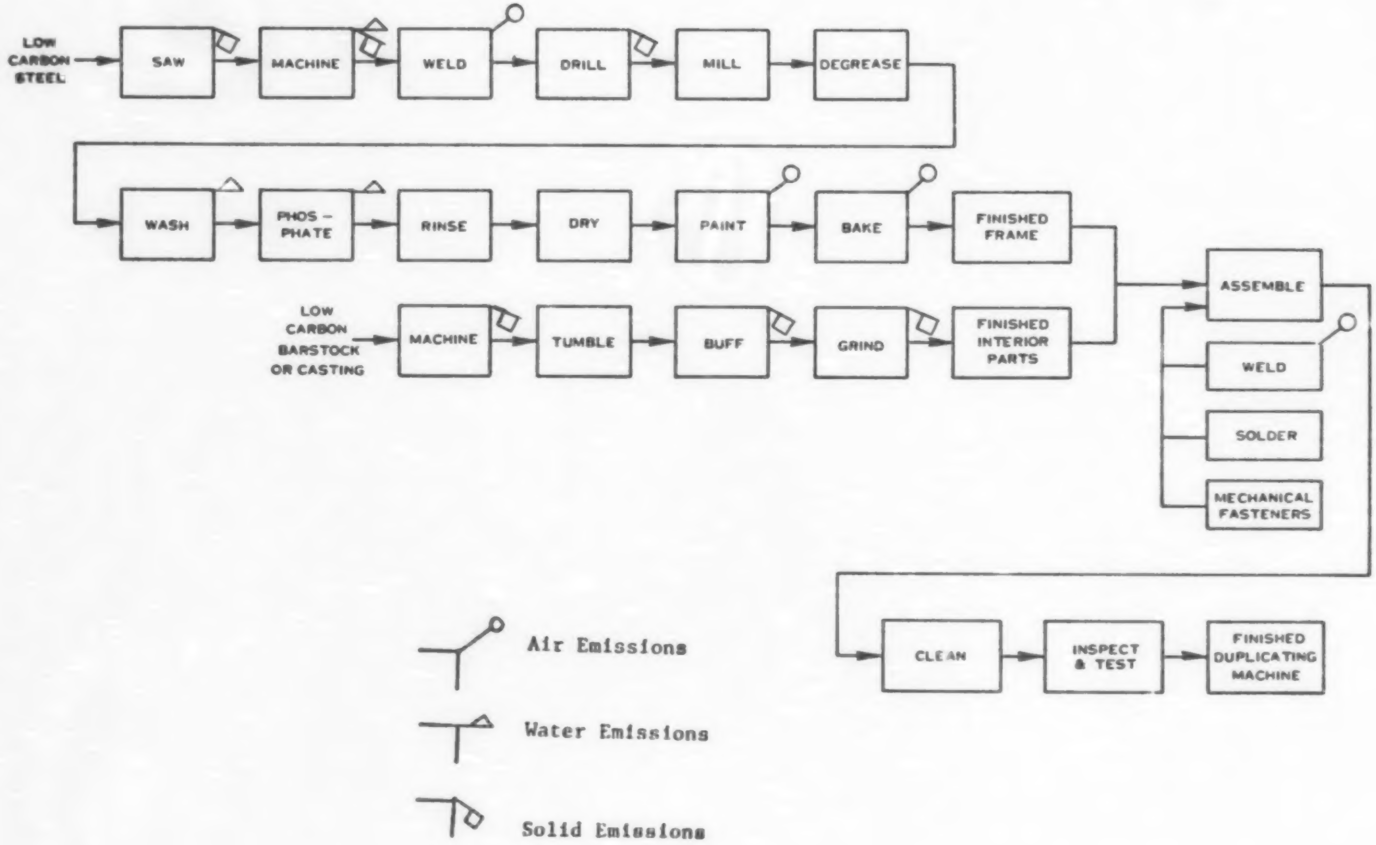
LOW CARBON STEEL
SAW
MACHINE
WELD
DRILL
MILL
DEGREASE
WASH
PHOS - PHATE
RINSE
DRY
PAINT
BAKE
FINISHED FRAME
LOW CARBON BARSTOCK OR CASTING
MACHINE
TUMBLE
BUFF
GRIND
FINISHED INTERIOR PARTS
ASSEMBLE
WELD
SOLDER
MECHANICAL FASTENERS
CLEAN
INSPECT & TEST
FINISHED DUPLICATING MACHINE
Air Emissions
Water Emissions
Solid Emissions

FIGURE 80. DUPLICATING MACHINE MANUFACTURING.

In 1972 there were 758 plants producing refrigeration and service industry equipment. These plants employed 149,800 people and shipped products valued at $7.0331 billion.(1)

Sheet metal is the major raw material used in this industry. In general, air conditioning and heating equipment is made by fabricating coils from tube or pipe, shearing and forming sheet metal for the case, machining and grinding forgings and castings (particularly for the compressor, condenser and fans), and assembling and hermetically sealing the individual components to make a complete unit.

The manufacture of an air conditioner (Figure 81) is representative of the refrigeration and heating equipment industry. An air conditioning unit basically consists of a compressor, condenser, evaporator, coils, fan filter, controls, and a case.

The making of coils is a typical example of air conditioner component manufacture. Coils are generally fabricated from copper, steel or aluminum tube, or iron pipe. When ferrous materials are used, they are protected externally, generally by hot-dip galvanizing. In some coils, fins are added. They may be wound on the tubes under pressure (in order to upset the metal slightly at the fin root) and are then given a coating of solder at the contact joint. In other types of coils, a spiral fin may be knurled into a shallow groove on the exterior of the tube. The tube may be expanded after the fins are assembled, or tube hole flanges of a flat or configurated fin may be made to override those in the preceding fin and so compress them upon the tube. There are also types of construction where the fin is formed from some of the material of the tube itself.

Waste Streams--

Process water is used mainly for cleaning and plating. Electrostatic painting is widely practiced in this industrial grouping thereby reducing the potential level of paint which reaches the waste streams. Welding is a significant contributor to the waste streams. Freon is used extensively by this industry. However, no estimates were readily available of the amounts lost to the atmosphere.

Tabular Data on Manufacturing Machinery and Equipment (except electrical)

Several tables are included that elaborate on the industry categories that were discussed earlier. These tables show the raw materials consumed, the unit operations, the wastes and media in which they occur, the potential levels of pollution (low, medium or high), and actions that are currently taken to alleviate pollution. Tables illustrating these industries are presented for the following types of products.

- Engines and turbines - Table 15
- Farm and garden machinery and equipment - Table 16

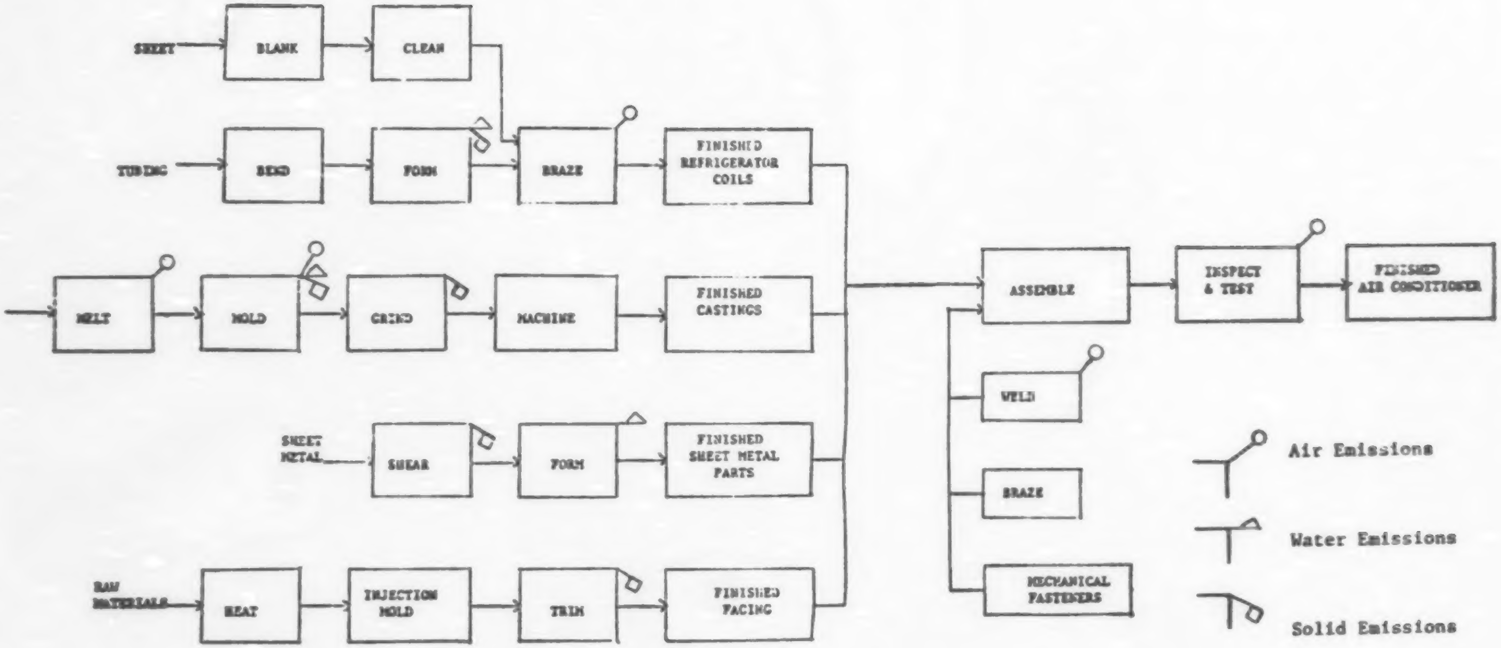
SHEET
BLANK
CLEAN
TUBING
BEND
FORM
BRAZE
FINISHED REFRIGERATOR COILS
MELT
MOLD
GRIND
MACHINE
FINISHED CASTINGS
SHEET METAL
SHEAR
FORM
FINISHED SHEET METAL PARTS
RAW MATERIALS
HEAT
INJECTION MOLD
TRIM
FINISHED FACING
ASSEMBLE
INSPECT & TEST
FINISHED AIR CONDITIONER
WELD
BRAZE
MECHANICAL FASTENERS
Air Emissions
Water Emissions
Solid Emissions

FIGURE 81. AIR CONDITIONER MANUFACTURING.

TABLE 15. MATERIALS AND PROCESS DATA FOR ENGINES AND TURBINES.

Operations[a]	Waste/Media	Potential Levels of Pollution	Current Action
Casting	dust/air,solids	high	filters
Machining	chips/solid	medium	recycle
Roll forming	oil/water	low	--
Stamping	oil/water	low	--
Welding	fumes/air	low	vent
Heat treating	HC/air	low	--
Assembling	oil/water	low	--
Riveting	--	--	--
Mechanical Fastenings	--	--	--
Lubricating	oil/water	medium	--
Painting	vapor/air,water	low	--
Electrochemical	--	--	--
machining	liquors/water	medium	neutralize
Degrease	vapors/air	locally high	vent

(a) The following raw materials are used in these operations: metals (sheet, bar, wire castings, forgings, extrusions), aluminum alloys, alloy & stainless steels, nickel alloys, cobalt alloys, titanium alloys, screw-machined products, plastics, oils, greases, acids, paints, ceramics, and degreasing agents.

TABLE 16. MATERIALS AND PROCESS DATA FOR FARM AND GARDEN MACHINERY AND EQUIPMENT.

Operations[(a)]	Waste/Media	Potential Levels of Pollution	Current Action
Sheet forming	oils/water	low	--
Machining	chips/solid	medium to high	recycle
Welding	fumes/air	medium/local	vent
Die casting	fumes/air	low	vent
Galvanizing	fumes/air	low	vent
Electroplating	liquors/water	low	neutralize
Heat treating	fumes/air	low	vent
Painting	fumes/air,water	medium	vent/water curtains

(a) The following raw materials are used in these operations: metals (bar, sheet, wire forgings, castings structurals), steels, zinc, copper, aluminum, fasteners, welding rod/wire, plastics, wood, paints, solvents, motors, and transmissions.

- Construction, mining and materials handling machinery and equipment - Table 17
- Metal working machinery and equipment - Table 18
- Special industry machinery, except metal working machinery - Table 19
- Materials and processes for general industrial machinery - Table 20
- Typical material and process for office computing and accounting machines - Table 21
- Materials and processes typical for refrigeration and service industry - Table 22.

ELECTRICAL AND ELECTRONIC MACHINERY

This product group includes establishments engaged in manufacturing machinery, apparatus and supplies for generation, storage, transmission, transformation and utilization of electrical energy. The manufacture of household appliances is also included in this group. Products include such diverse items as generators, Christmas tree lights, and microwave ovens. Although no single company or group of companies dominates this industry, General Electric and Westinghouse are probably the largest firms. In 1972 this industry product group consisted of 11,964 plants, employed 1,650,000, persons and shipped products valued at $96.7233 billion.

The segments of the electrical and electronic machinery industry included in this analysis consist of the following categories:

- Power, distribution, and specialty transformers
- Motors and generators
- Carbon and graphite products
- Welding apparatus, electric
- Household cooking equipment
- Household vacuum cleaners
- Electric housewares and fans
- Electric lamps
- Phonograph records and prerecorded magnetic tape
- Telephone and telegraph apparatus

TABLE 17. MATERIALS AND PROCESS DATA FOR CONSTRUCTION, MINING AND MATERIALS HANDLING MACHINERY AND EQUIPMENT.

Operations[a]	Waste/Media	Potential Levels of Pollution	Current Action
Sheet-forming	oil/water	low	--
Torch cutting	fumes/air	high/local	vent
Welding	fumes/air	medium/local	--
Machining	oils/water	medium	--
Electroplating	liquors/water	low	--
Painting	fumes,overspray/ air,water	medium	vent/water curtains
Baking	fumes/air	low	vent
Heat treating	fumes(HC)/air	low	vent
Pickling	liquors/water	medium	neutralize
Bonderizing	liquors/water	low	neutralize
Forging	scale,scrap/solids	low	--
Casting	vapors	medium	--
Assembling	oils/water	medium	--
Fastening	--	--	--

(a) The following raw materials are used in these operations: metals (sheet, plate, structurals, wire, bar, forgings, castings), steels, copper alloys, aluminum, brazing alloys, fasteners, batteries, plastics, oils, greases, acids, rubber products, glass, electromagnets, fabricated components, wheels and bearings, steering gear, pumps, and radiators.

TABLE 18. MATERIALS AND PROCESS DATA FOR METALWORKING MACHINERY AND EQUIPMENT.

Operations [(a)]	**Waste/Media**	**Potential Levels of Pollution**	**Current Action**
Casting	fumes,slags/air,solids	medium	--
Forging	fumes/air	--	--
Machining	chips/solids	high	recycle
Plate forming	oil/water	low	--
Welding	fumes/air	medium	vent
Brazing	fumes/air	low	--
Grinding and Polishing	solids	low	--
Torch cutting	fumes,slags/air,solids	medium	--
Heat treating	fumes HC/air	low	vent
Painting	vapors,solids/air,water	medium	--
Electroplating	liquors/water	low	neutralize
Lubricating	oils/water	medium	--

(a) The following raw materials are used in these operations: metals (castings, forgings structurals, wire, tubing, sheet, plate), carbon and alloy steel, copper and alloys, aluminum, brazing alloys, tool steels, fasteners, and glass.

TABLE 19. MATERIALS AND PROCESS DATA FOR SPECIAL INDUSTRY MACHINERY, EXCEPT METALWORKING MACHINERY.

Operations[a]	Waste/Media	Potential Levels of Pollution	Current Action
Plate forming	oils/water	low	--
Stamping	oil/water	low	--
Machining	chips/solid	low	recycle
Welding	fumes/air	medium	vent
Brazing	fumes/air	low	vent
Soldering	fumes/air	low	vent
Grinding & Polishing	dust/air,water,solid	medium	water/fill
Torch cutting	fumes/air	medium/local	vent
Lubricating	oil/water	low	--
Bright Annealing	fumes HC/air	low	--
Heat Treatment	fumes/air	low	--
Electroplating	acids/water	medium	--
Pickling	acids,alkali/water	low	--
Painting	HC/air,water	medium	--
Baking	HC/air	low	--
Adhesive bonding	HC/air,water	low	--
Coining	--	--	--
Assembling	oils/water	low	--

(a) The following raw materials are used in these operations: metals (sheet, structurals plate, castings, forgings, wire), iron, carbon and alloy steels, stainless steels, zinc alloys, copper and alloys, nickel (plating), chromium (plating) brass and bronze (bearings), aluminum alloys, lead alloys, oil, grease, plastics, paints, solvents, acids/alkali, and wood.

TABLE 20. MATERIALS AND PROCESSES FOR GENERAL INDUSTRIAL MACHINERY AND EQUIPMENT.

Operations[a]	**Waste/Media**	**Potential Levels of Pollution**	**Current Action**
Casting	**fumes(HC),slags/air, solid,water**	**high**	**vent**
Plate forming	**oil/water**	**low**	--
Stamping	**oil/water**	**low**	--
Machining	**oil/water**		--
Welding	**fumes/air,solids**	**medium**	**vent**
Brazing	**fumes/air**	**low**	--
Soldering	**fumes/air**	**low**	--
Heat treating	**fumes/air**	**low**	**vent**
Grinding & Polishing	**dust,solids/air,water**	**low**	--
Electroplating	**metal salts/water**	**medium**	--
Pickling	**acids/water**	**medium**	--
Painting	**fumes(HC)/air,water**	**medium**	--
Riveting	--	--	--
Assembling	**oil/water**	**low**	--
Lubricating	**fumes,HC/water,air**	**low**	--
Lining of furnaces	**dust,asbestos/air, water**	**medium**	**vent**

(a) The following raw materials are used in these operations: metals (sheet, plate structurals, castings forgings, bar, billet wire, tubing), steel (carbon, alloy) aluminum, zinc alloys, copper and alloys, iron, plastics, wood, oil, grease, paints, solvents, acids/alkali, refractories, and asbestos.

TABLE 21. TYPICAL MATERIAL AND PROCESS FOR OFFICE, COMPUTING AND ACCOUNTING MACHINES.

Operations [a]	Waste/Media	Potential Levels of Pollution	Current Action
Die Casting	Fumes/air	low	--
Sheet forming	oil/water	low	--
Powder compaction	--	--	--
Sintering	fumes(HC)/air	low	vent
Stamping	oil/water	low	--
Blanking	trimmings/solid	low	--
Brazing	fumes/air	low	--
Painting	fumes(HC)/air,water	low	vent
Molding	oils/water	low	--
Baking	fumes(HC)/air	low	--
Lubricating	oils/water	low	--
Welding	fumes/air	low	vent
Pickling	acid/water	low	--
Machining	chips/solid	low	--
Phosphating	soaps/water	medium	--
Assembling	oil/water	low	--

(a) The following raw materials are used in these operations: metals (die castings sheet, structurals, extrusions, powders, wire, stampings) steel, aluminum alloys, zinc alloys, copper and alloys, lead, tin, plastics, paint, oil, acids/alkali, fiber board, and rubber.

TABLE 22. MATERIALS AND PROCESSES TYPICAL FOR REFRIGERATION AND SERVICE INDUSTRY MACHINERY.

Operations[a]	Waste/Media	Potential Levels of Pollution	Current Action
Casting(die)	fumes/air	low	vent
Plate and Sheet forming	oil/water	low	--
Machining	oil/water	medium	--
Welding	fumes,slag/air,solid	medium/local	vent
Brazing	fumes/air	low	--
Soldering	fumes,lead/solid	medium	--
Grinding and polishing	dust/water,solid	medium	--
Heat treating	fumes(HC)/air	low	--
Electroplating	fumes,acids/air,water	medium	--
Pickling	liquors/water	low	neutralize
Painting	fumes(HC)/air,water	medium	--
Baking	fumes(HC)/air	low	--
Assembling	oil/water	medium	--
Charging of Freon	Freon/air	relatively high for industry	--

(a) The following raw materials are used in these operations: metals (sheet, plate, wire, powders, castings forgings, tubing), steel, aluminum alloys, copper and alloys, tin, lead, zinc, iron, fasteners, plastics, wood, oil, grease, paints, and freon.

- Semiconductors and related devices

- Electronic capacitors

- Storage batteries.

Descriptions of manufacturing processes and flow diagrams were excerpted from Reference 37.

Power, Distribution, and Specialty Transformers

This industry includes establishments primarily engaged in manufacturing power, distribution, instrument, and specialty transformers. Power, distribution and specialty transformers were produced by 216 plants and had a value of primary products shipped at $1.3874 billion in 1972. Most of these plants (64 percent) employ more than 20 workers. Approximately 67 percent of the transformers produced are fluorescent lamp ballasts, 31 percent are specialty transformers, and 2 percent are for miscellaneous uses.

Manufacturing Processes--

Steel insulated wire and cable, copper and copper-based alloys, and aluminum and aluminum-based alloys are the major raw materials. The principal manufacturing operations are mechanical material removal, material forming, and material coating.

In general, transformers are made by stamping out steel core laminations, binding them together, fitting a prewound coil over the core, drying and sealing the core, and assembling the coil and core in a sheet metal tank.

The manufacture of power transformers (Figure 82) is representative of the transformer industry. The manufacturing starts with silicon steel stock which is pretreated in a pickling bath and then rinsed. The laminations are cut, punched,and then coated with varnish and bonded together. The coils are then wound on the forms and impregnated with a sealer such as oil. The coil is then installed on the core and the core/coil assembly is dried. The assembly is then installed in an oil tank made from paint structural steel. This tank has plumbing to circulate the oil for cooling. Some transformers are filled with a cooling oil containing polychlorobiphenyls (PCBs).

Waste Streams--

Process water used by the industry is used mainly for a water rinse after a pickling operation in a bath, usually a 5-80 percent concentration of sulfuric acid at 65-88 C (150-190 F). Vapor degreasing is also done with solvents such as trichloroethylene, perchloroethylene, or trichloroethane which must be rinsed away using water. Air emissions result from coating, grinding, and degreasing operations. Solid waste results from shearing, cutting, and punching operations.

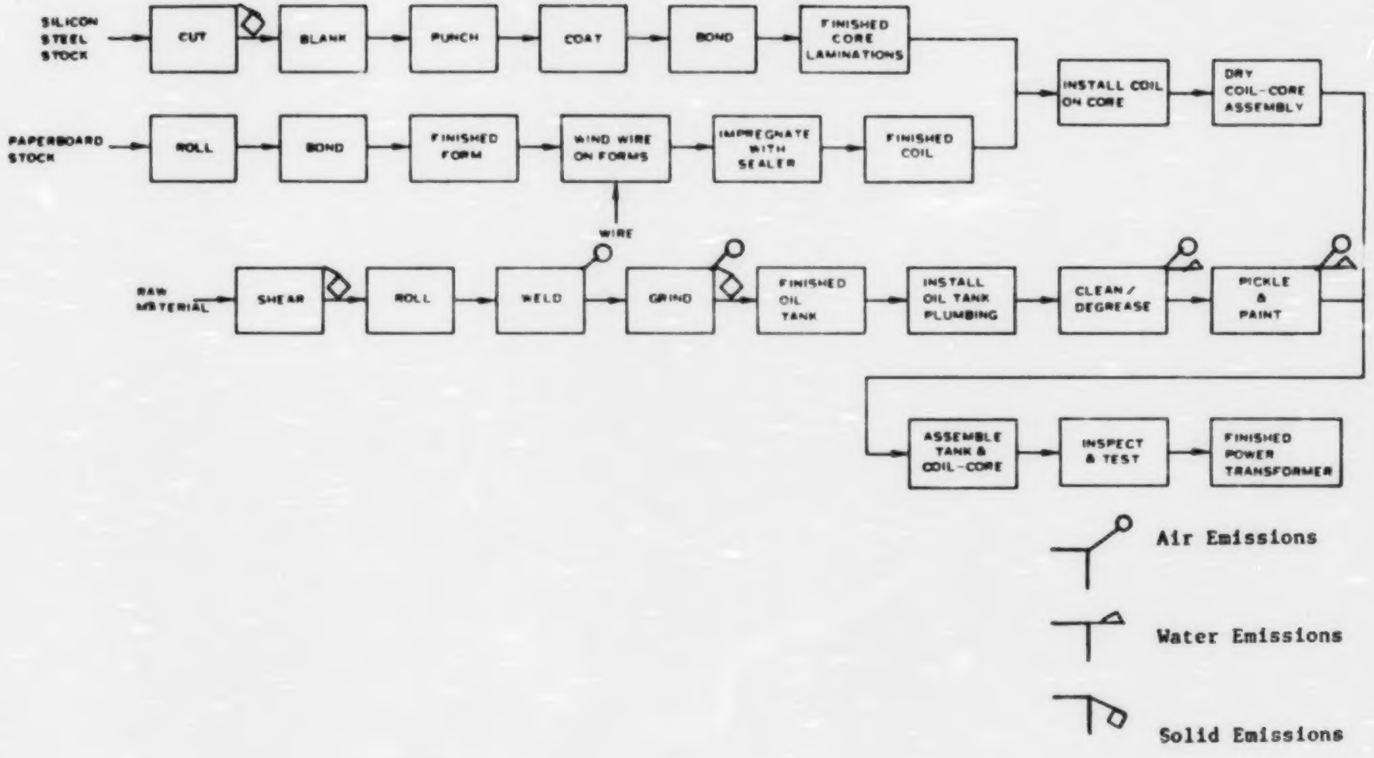
SILICON STEEL STOCK
CUT
BLANK
PUNCH
COAT
BOND
FINISHED CORE LAMINATIONS
PAPERBOARD STOCK
ROLL
BOND
FINISHED FORM
WIND WIRE ON FORMS
WIRE
IMPREGNATE WITH SEALER
FINISHED COIL
INSTALL COIL ON CORE
DRY COIL-CORE ASSEMBLY
RAW MATERIAL
SHEAR
ROLL
WELD
GRIND
FINISHED OIL TANK
INSTALL OIL TANK PLUMBING
CLEAN / DEGREASE
PICKLE & PAINT
ASSEMBLE TANK & COIL-CORE
INSPECT & TEST
FINISHED POWER TRANSFORMER
Air Emissions
Water Emissions
Solid Emissions

FIGURE 82. POWER TRANSFORMER MANUFACTURING.

Motors and Generators

This industry includes establishments primarily engaged in manufacturing electric motors (except starting motors) and power generators; motor generator sets; railway motors and control equipment; and motors, generators, and control equipment for gasoline, electric, and oil-electric buses and trucks.

Motors and generators were produced by 426 plants, and had a value of primary products shipped at $2.1448 billion in 1972. Most of these plants (60 percent) employ more than 20 workers. Of all the motors and generators manufactured in 1972, 96 percent were fractional horsepower motors, 2 percent were integrated horsepower motors, less than 1 percent were prime mover generator sets and less than 1 percent were motor generator sets.

Manufacturing Processes--

Steel, copper, aluminum castings and semiconductors are the major raw materials. The principal manufacturing operations are mechanical material removal, material forming, material coating, and assembly operations.

In general, motors and generators are made by forming the rotor and then winding the rotor and stator. The body frame and end bells are then formed and assembled with the rotor, stator, and other piece parts. The unit is then cleaned, painted,and tested.

The manufacture of motors (Figure 83) is representative of the industry. A typical motor is constructed by starting with silicon steel stock that is cleaned in a pickling bath and rinsed. This stock is then used for the laminations which are formed by insulating, shearing into strips and blanking into circles. Next, the stator laminations are notched. The laminations are then stacked and tack welded together forming the rotor and stator cores. The rotor and stator cores are next wound, dipped in lacquer, and baked.

The body frame and bells are made from rough castings which are machined, cleaned, and primed. The motor shaft is machined and chamfered, and a key-way cut. The motor shaft is pressed into the rotor and then the rotor is balanced.

The stator is assembled to the frame and the rotor and bearings are installed. The assembled motor is cleaned, painted, and tested.

Waste Streams--

Process water is used mainly for the pickling bath rinse. Otherwise, this industry uses little or no water. Air emissions result from baking, painting, welding, and grinding operations. Solid waste results from grinding, shearing, and drilling operations.

Carbon and Graphite Products

This industry includes establishments primarily engaged in manufacturing

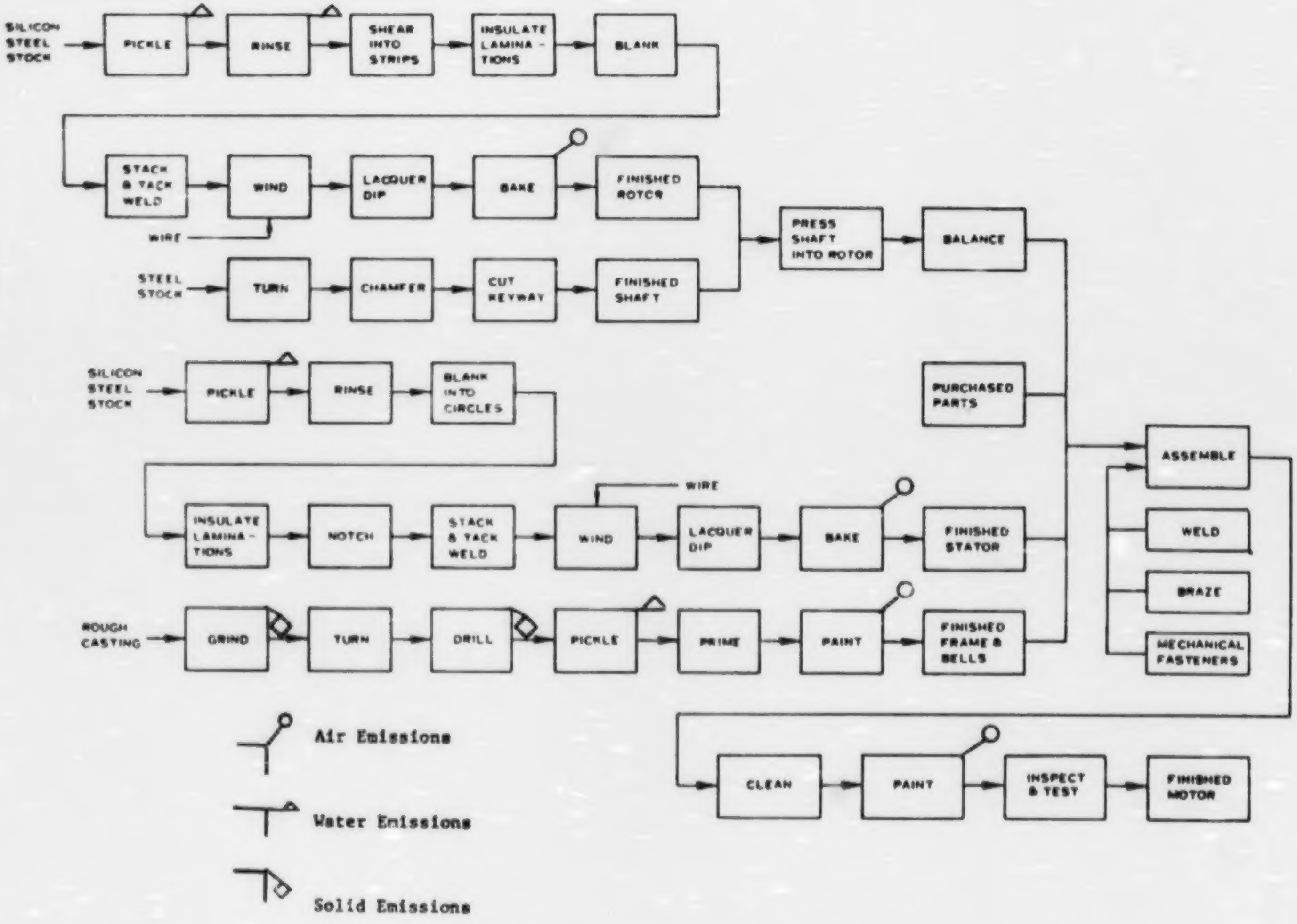
SILICON STEEL STOCK
PICKLE
RINSE
SHEAR INTO STRIPS
INSULATE LAMINATIONS
BLANK
STACK & TACK WELD
WIND
WIRE
LACQUER DIP
BAKE
FINISHED ROTOR
STEEL STOCK
TURN
CHAMFER
CUT KEYWAY
FINISHED SHAFT
PRESS SHAFT INTO ROTOR
BALANCE
SILICON STEEL STOCK
PICKLE
RINSE
BLANK INTO CIRCLES
PURCHASED PARTS
INSULATE LAMINATIONS
NOTCH
STACK & TACK WELD
WIND
WIRE
LACQUER DIP
BAKE
FINISHED STATOR
ROUGH CASTING
GRIND
TURN
DRILL
PICKLE
PRIME
PAINT
FINISHED FRAME & BELLS
ASSEMBLE
WELD
BRAZE
MECHANICAL FASTENERS
CLEAN
PAINT
INSPECT & TEST
FINISHED MOTOR
Air Emissions
Water Emissions
Solid Emissions

FIGURE 83. ELECTRIC MOTOR MANUFACTURING.

lighting carbons; carbon, graphite, and metal-graphite brushes and brush stock; carbon or graphite electrodes for thermal and electrolytic uses; and other carbon, graphite, and metal-graphite products. The major products are:

- Brush blocks, carbon or molded graphite
- Brushes and brush stock contacts: carbon, graphite, etc. - electric
- Carbon specialties for electrical use
- Carbons, electric
- Electrodes, for thermal and electrolytic uses: carbon and graphite
- Lighting carbons.

Carbon and graphite products were produced by 72 plants, and had a value of primary products shipped at $374.8 million in 1972. Most of these plants (62 percent) employ more than 20 workers. Forty percent of the dollar value produced in this category is from electrodes, 17 percent from brushes, contacts and brushplates, and 43 percent from other carbon and graphite products.

Manufacturing Processes--

Carbon, insulated wire, and cable and copper are the major raw materials. The principal manufacturing operations are mechanical material removal, material forming (metals), and casting and molding (metals).

Carbon and graphite products such as motor brushes are made by pressing the carbon into the desired form, baking it in a furnace and treating with a metallic halide.

The manufacture of motor brushes (Figure 84) is representative of the carbon and graphite products industry. A mixture of carbon and a metal (powder) such as silver or copper is pressed in a mold to form the brushes. Sometimes a pigtail is embedded into the carbon before molding to provide electrical contacts. The pigtail is formed by cutting insulated extra flexible stranded wire to the proper length, stripping the two ends of insulation, and twisting the leads. A contact lug is sometimes crimped onto the exposed end of the wire. After pressing, the motor brush is then baked. The brush is finally treated by dipping with a metallic halide such as lead iodide which is sometimes added prior to pressing and baking. The lead iodide produces a lubricating film which helps to increase the life of the brush.

Waste Streams--

Process water is used mainly for cleaning. Air emissions result from the baking and mixing operations.

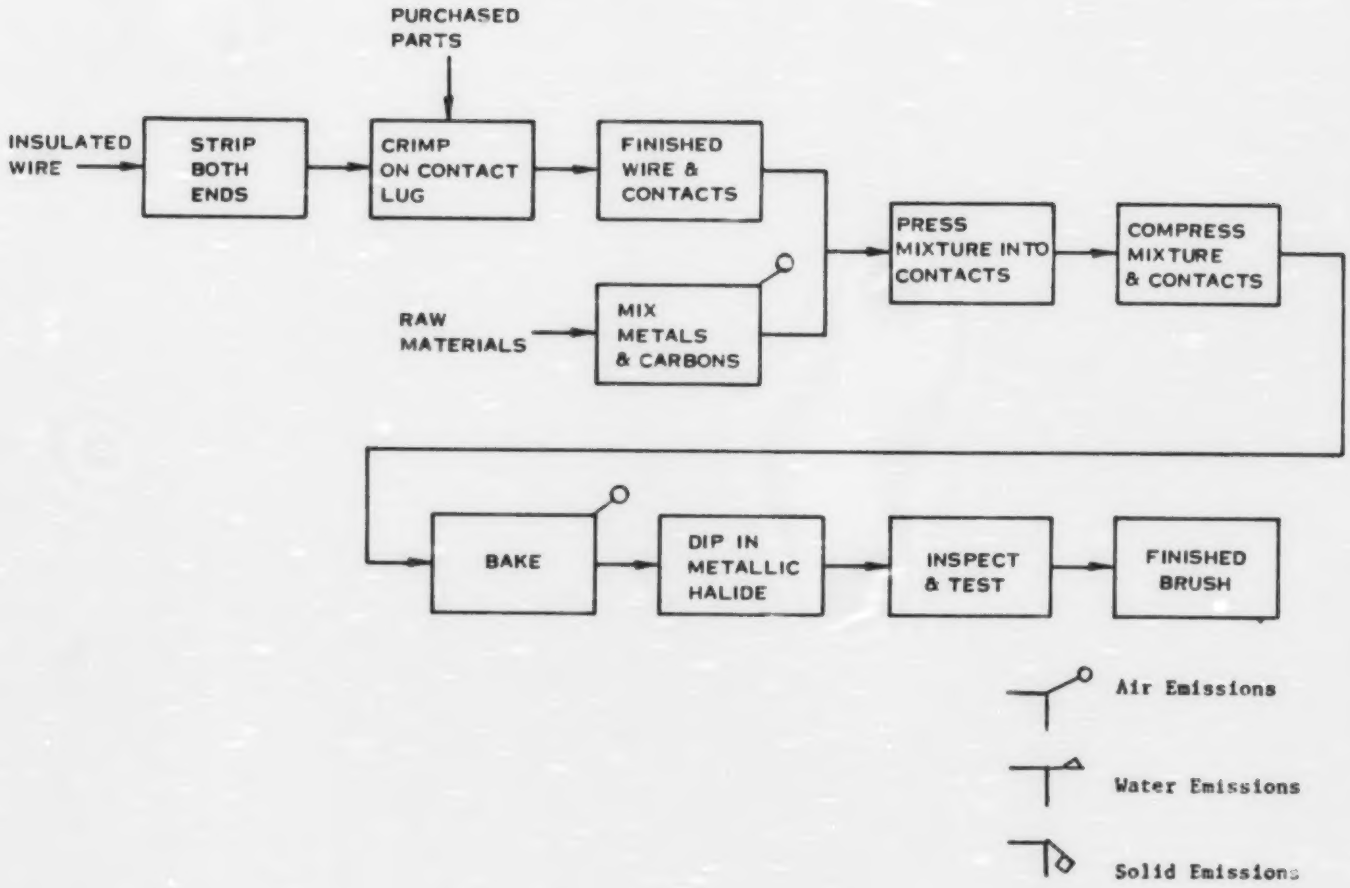
PURCHASED PARTS
INSULATED WIRE
STRIP BOTH ENDS
CRIMP ON CONTACT LUG
FINISHED WIRE & CONTACTS
RAW MATERIALS
MIX METALS & CARBONS
PRESS MIXTURE INTO CONTACTS
COMPRESS MIXTURE & CONTACTS
BAKE
DIP IN METALLIC HALIDE
INSPECT & TEST
FINISHED BRUSH
Air Emissions
Water Emissions
Solid Emissions

FIGURE 84. MOTOR BRUSH MANUFACTURING.

Welding Apparatus, Electric

This industry includes establishments primarily engaged in manufacturing electric welding apparatus and accessories. Establishments primarily engaged in coating welding wire from purchased wire or from wire drawn in the same establishments are also included.

Electric welding apparatus was produced by 166 plants, and shipped primary products were valued at $524.4 million in 1972. Most of these plants (54 percent) employ fewer than 20 workers. Approximately 30 percent of the electric welder products manufactured are arc welders, 69 percent are arc-welding electrodes, and 1 percent are resistance welders.

Manufacturing Processes--

Steel, insulated wire and cable, aluminum and aluminum-based alloys and copper castings are the major raw materials. The principal manufacturing operations are mechanical material removal, material coating, and assembly operations.

In general, electric welders are made by assembly of the transformer, control panel, fan, and cable harness into a metal enclosure.

The manufacture of AC transformer welding apparatus (Figure 85) is representative of the welding apparatus industry. The sheet metal stock is first pretreated in a sulfuric acid bath. The metal components such as the cabinet are fabricated and the skids are welded to the baseplate. The covers, skids, and other metal components are then painted. The transformer, which can either be purchased or manufactured in-house, is assembled to the baseplate along with the control panel, fan and cable harness. The unit is then inspected and tested, the covers are assembled, and the unit is cleaned.

Waste Streams--

Process water is used mainly for rinsing after pretreating and degreasing. The pretreating consists of a sulfuric acid bath with a water rinse. Vapor degreasing is done with trichloroethylene or trichloroethane. Air emissions result from the welding and painting.

Household Cooking Equipment

This industry includes establishments primarily engaged in manufacturing household cooking equipment, both electric and nonelectric types. The major products are:

- Barbecues, grills, and braziers for outdoor cooking
- Cooking equipment, household
- Gas ranges, domestic
- Microwave ovens, household

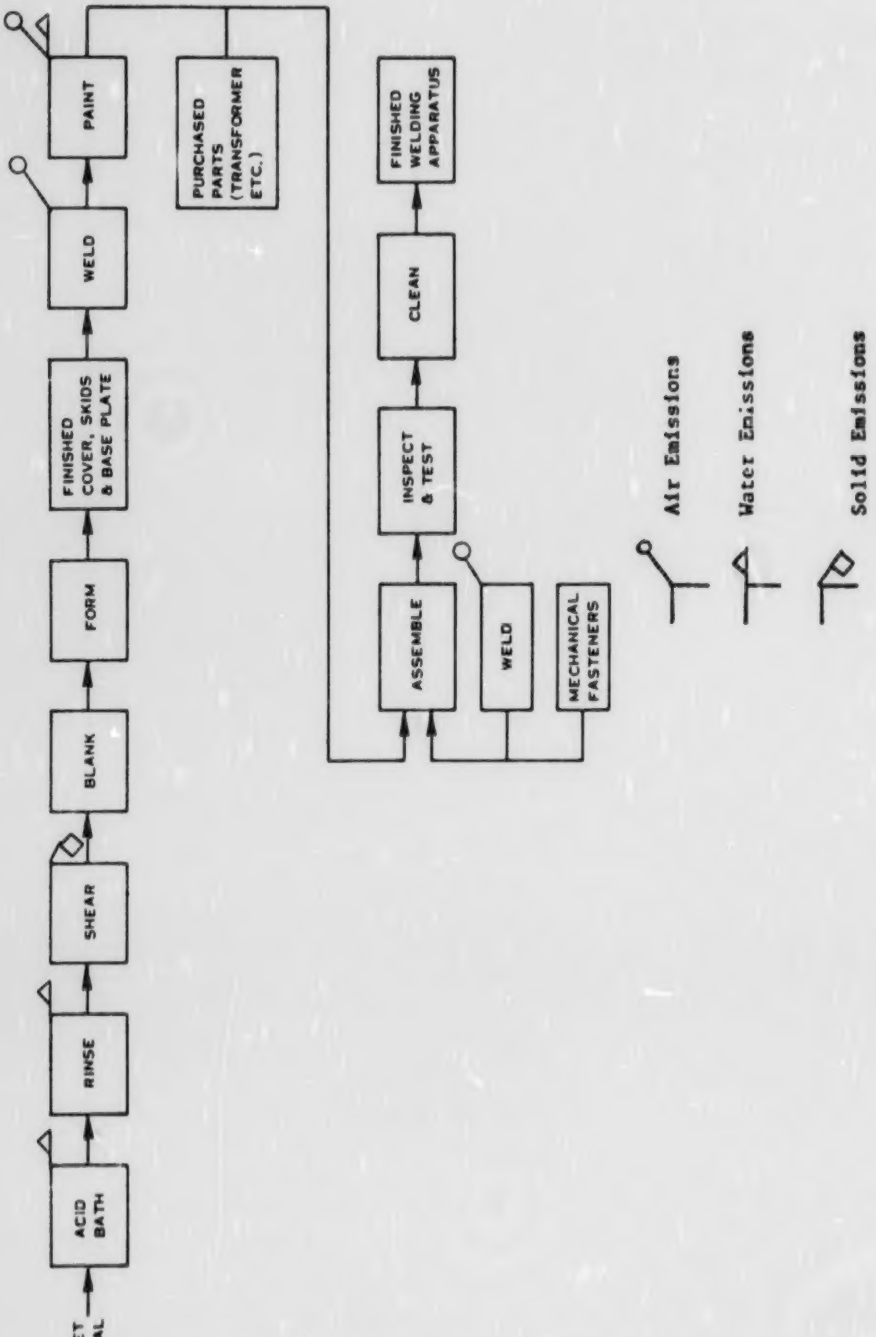
SHEET METAL
ACID BATH
RINSE
SHEAR
BLANK
FORM
FINISHED COVER, SKIDS & BASE PLATE
WELD
PAINT
PURCHASED PARTS (TRANSFORMER ETC.)
ASSEMBLE
WELD
MECHANICAL FASTENERS
INSPECT & TEST
CLEAN
FINISHED WELDING APPARATUS
Air Emissions
Water Emissions
Solid Emissions

FIGURE 85. WELDING APPARATUS (ELECTRIC) MANUFACTURING.

- Ovens, household: except portable
- Ranges: electric, gas, etc. - household
- Stoves, disk.

In 1972, household cooking equipment was produced by 82 plants and had a value of primary products shipped at $763.8 million. Most of these plants (60 percent) employ more than 20 workers. Fifty-six percent of the household cooking equipment is electric ranges and ovens and 44 percent is non-electric cooking equipment.

Manufacturing Processes--

Steel, aluminum and aluminum-based alloys, castings, electric motors, and timers are the major raw materials. The principal manufacturing operations are material forming (metal), material coating, mechanical material removal, and casting and molding (metals).

In general, household cooking equipment is made by bending and forming sheet steel stock into the outer housing shape, welding it, and assembling components to it.

The manufacture of electric ranges (Figure 86) is representative of the household cooking equipment industry. Sheet steel stock is first cleaned and galvanized. It is then cut and trimmed to the proper size and holes are cut for burners, controls, etc. The stock is next bent and formed for the side panels, top surface, control box, oven sidewalls, and doors. The frame is then cut and welded together. The unit is cleaned in a pickling bath and vapor degreased with trichloroethylene, perchloroethylene, or trichloroethane, and all surfaces are primed. The outside surfaces are painted with a high heat-resistant compound and the fixtures and trim are electroplated. Electric burners are made by embedding resistance coils in fused magnesium oxide powder or refractory cement. The oven sidewalls are installed on the frame and they are packed with fiber glass or asbestos insulation and assembled with sheet metal screws. The burner and controls are installed next and wired. The oven is then inspected and tested.

Waste Streams--

Process water is used mainly for cleaning of the metal stock after pickling and vapor degreasing. Air emissions result from galvanizing, welding, pickling, vapor degreasing, enameling, and plating. Solid waste results from the cutting and trimming, and shearing operations.

Household Vacuum Cleaners

This industry includes establishments primarily engaged in manufacturing vacuum cleaners for household use.

Household vacuum cleaners were produced by 36 plants, and shipped primary products were valued at $372 million in 1972.

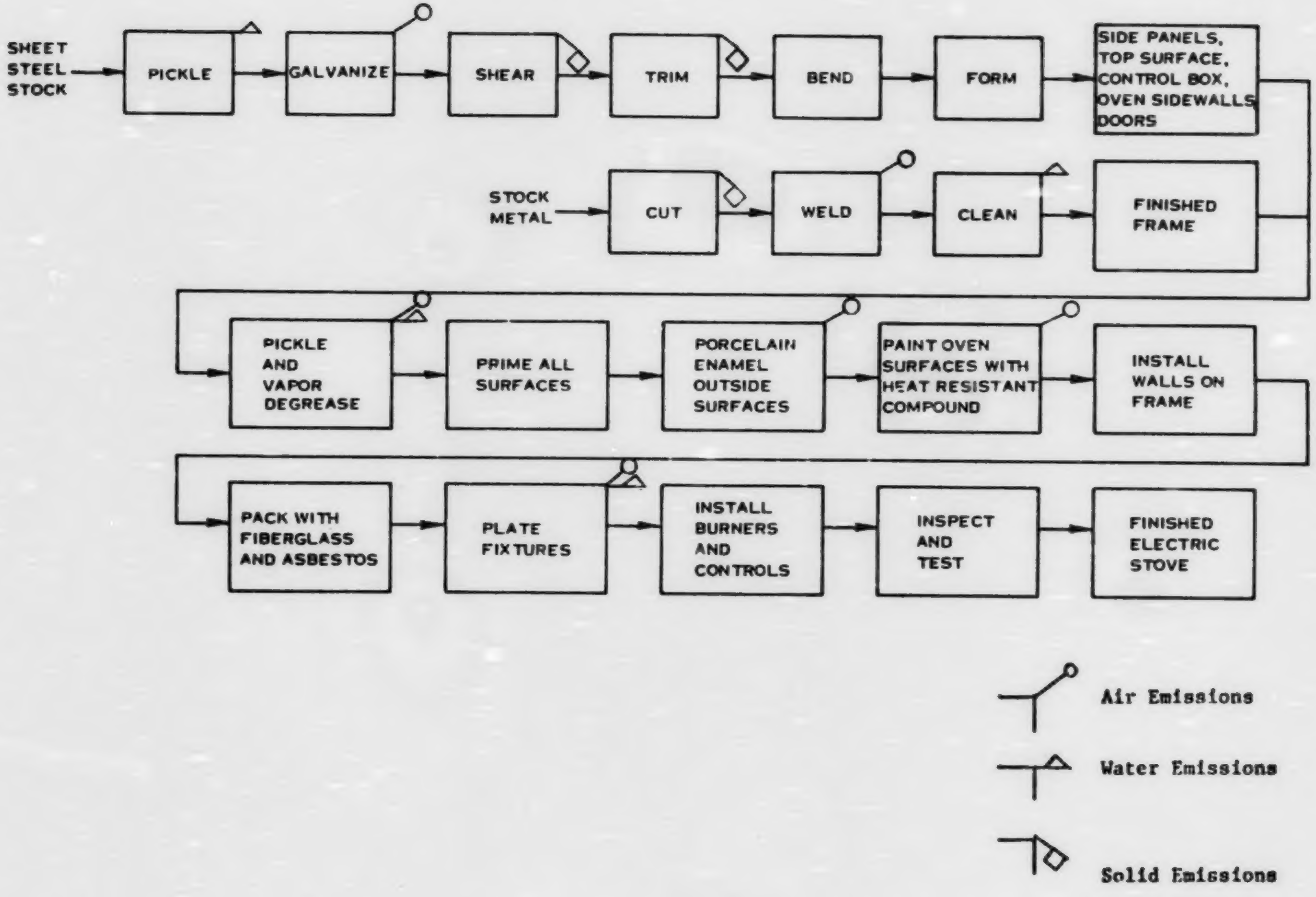
SHEET STEEL STOCK
PICKLE
GALVANIZE
SHEAR
TRIM
BEND
FORM
SIDE PANELS, TOP SURFACE, CONTROL BOX, OVEN SIDEWALLS DOORS
STOCK METAL
CUT
WELD
CLEAN
FINISHED FRAME
PICKLE AND VAPOR DEGREASE
PRIME ALL SURFACES
PORCELAIN ENAMEL OUTSIDE SURFACES
PAINT OVEN SURFACES WITH HEAT RESISTANT COMPOUND
INSTALL WALLS ON FRAME
PACK WITH FIBERGLASS AND ASBESTOS
PLATE FIXTURES
INSTALL BURNERS AND CONTROLS
INSPECT AND TEST
FINISHED ELECTRIC STOVE
Air Emissions
Water Emissions
Solid Emissions

FIGURE 86. WELDING APPARATUS (ELECTRIC) MANUFACTURING.

Manufacturing Processes--

Steel, insulated wire and cable, copper and copper-based alloys, aluminum and aluminum-based alloys, castings, and electric motors are the major raw materials. The principal manufacturing operations are mechanical material removal, material forming, material coating, and electrochemical processing.

In general, vacuum cleaners are made by casting and machining the body, then fabricating the components, and finally assembling these parts to the body.

The manufacture of canister vacuum cleaners (Figure 87) is representative of the vacuum cleaner industry. Initially two plastic halves which form the canister body are molded and the excess plastic is trimmed. Handles, covers, and attachments (such as brush housings) are also molded in plastic. The wands are rolled metal tubing with knurled ends or extruded plastic. Metal trim is stamped, degreased, pickled, and electroplated. This trim is then screwed or bonded to the canister halves. Purchased motors, switches and wires are installed next, and the canister halves are bolted together and covers attached. The vacuum cleaner is tested and then packaged along with accessories.

Waste Streams--

Process water is used mainly for rinses after cleaning, vapor degreasing, and postplating rinses. Air emissions result from the plating, welding, and degreasing operations. Solid waste results from trimming and stamping operations.

Electric Housewares and Fans

This industry includes establishments primarily engaged in manufacturing electric housewares for heating, cooking, and other purposes; and electric fans, including ventilating and exhaust household-type fans.

Electric housewares and fans were produced by 299 plants and shipped primary products were valued at $1.3184 billion in 1972. Most of these plants (56 percent) employ more than 20 workers. Twelve percent of the products produced in this category are electrical fans, 6 percent are electric razors, and 82 percent are other small appliances.

Manufacturing Processes--

Steel, copper and copper-based alloys, aluminum and aluminum-based alloys, castings, timing mechanisms, and electric motors are the major raw materials used by this industry. The principal manufacturing operations are material forming (metals), material coating, and mechanical material removal.

Electric housewares and fans are made by a wide range of manufacturing processes. Most typically, machining or plastic molding is used to manufacture the shell of the unit. Welding is used to attach parts, some of

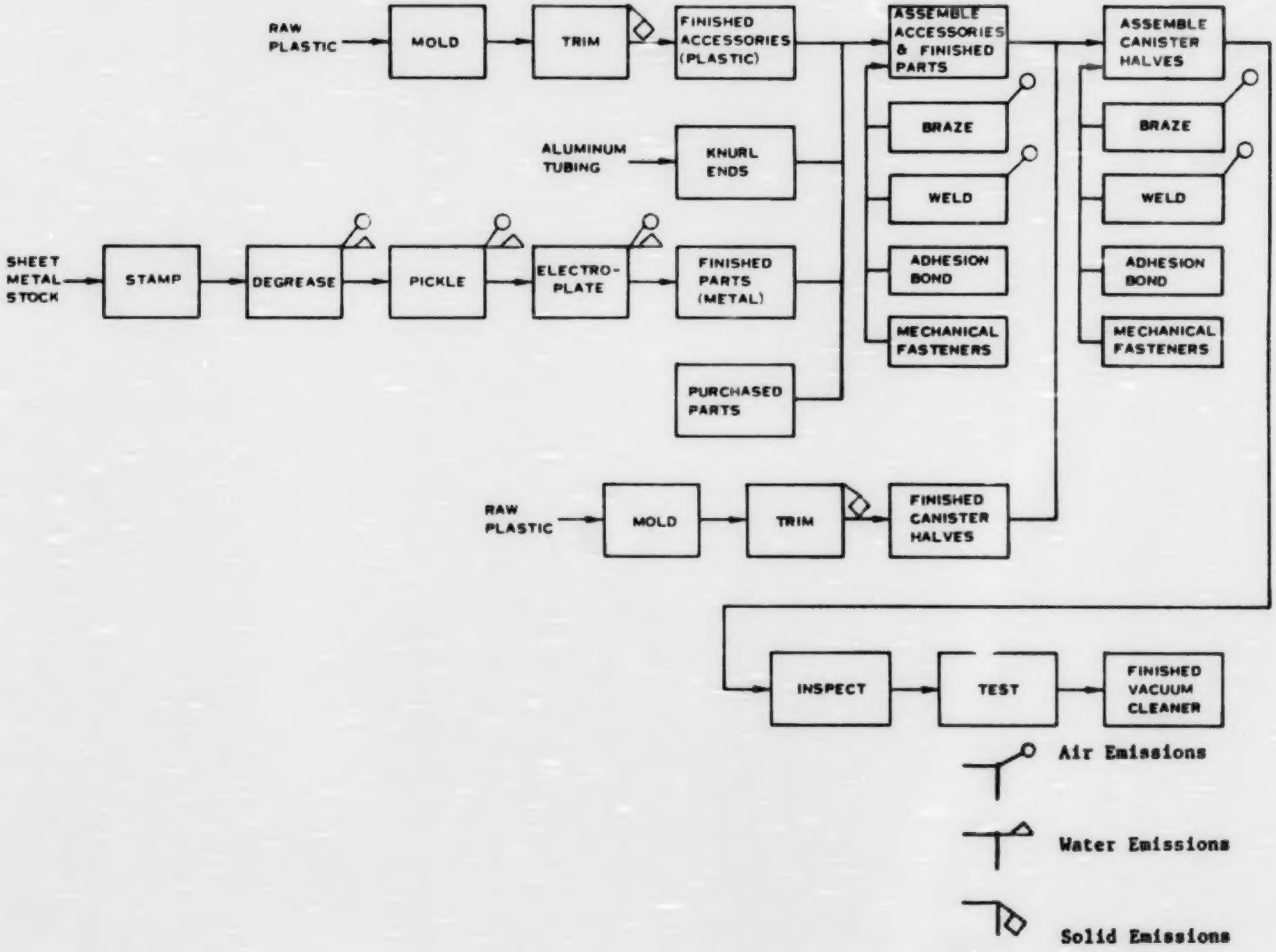
RAW PLASTIC
MOLD
TRIM
FINISHED ACCESSORIES (PLASTIC)
ALUMINUM TUBING
KNURL ENDS
SHEET METAL STOCK
STAMP
DEGREASE
PICKLE
ELECTRO-PLATE
FINISHED PARTS (METAL)
PURCHASED PARTS
ASSEMBLE ACCESSORIES & FINISHED PARTS
BRAZE
WELD
ADHESION BOND
MECHANICAL FASTENERS
ASSEMBLE CANISTER HALVES
BRAZE
WELD
ADHESION BOND
MECHANICAL FASTENERS
RAW PLASTIC
MOLD
TRIM
FINISHED CANISTER HALVES
INSPECT
TEST
FINISHED VACUUM CLEANER
Air Emissions
Water Emissions
Solid Emissions

FIGURE 87. VACUUM CLEANER MANUFACTURING.

which are electroplated. Finished products are usually painted.

The manufacture of food mixers (Figure 88) is representative of the electric housewares and fans industry. The shell of the mixer is made by turning and grinding a rough metal casting or by plastic molding. Rolling, swaging, bending, and forming are used to make the beaters which are then tumbled to remove any burrs, and electroplated. Two halves of the unit are butted together to form the assembly which is then cleaned by pickling and neutralized in an alkaline solution. The unit is then electroplated or painted. Plastic parts are either molded in-house or purchased. Assembly of all components is the last operation and includes soldering of electrical connections. Electric motors are either purchased or manufactured. Gears are formed by machining and tempering or by plastic molding.

Waste Streams--

Process water, which constitutes 43 percent of the gross water used by the industry, is used mainly for cleaning prior to and after such processes as bright dipping, and in rinses in electroplating. Other sources of effluent water are air scrubbers used in the painting operation. Air emissions result from the electroplating, painting, welding, and grinding operations.

Electric Lamps

This industry includes establishments primarily engaged in manufacturing electric bulbs, tubes, and related light sources. Important products of this industry include:

Bulbs, electric light: complete
Electrotherapeutic lamp units for ultraviolet and infrared radiation
Flashlight bulbs, photographic
Glow lamps
Infrared lamps
Lamps, electric: incandescent filaments, fluorescent, and vapor
Lamps, sealed beam
Light bulbs, electric: complete
Photoflash and photoflood lamps
Pilot lights, radio
Strobotrons
Tubes, electric light
Ultraviolet lamps.

Electric lamps were produced by 142 plants and shipped primary products were valued at $1.025 billion in 1972. Half of these plants (50 percent) employ more than 20 workers. Of the products produced in this category, 33 percent are photographic incandescent bulbs, 34 percent are large incandescent bulbs, 20 percent are miniature incandescent bulbs, 8 percent are electric discharge, and 5 percent are Christmas tree lamps.

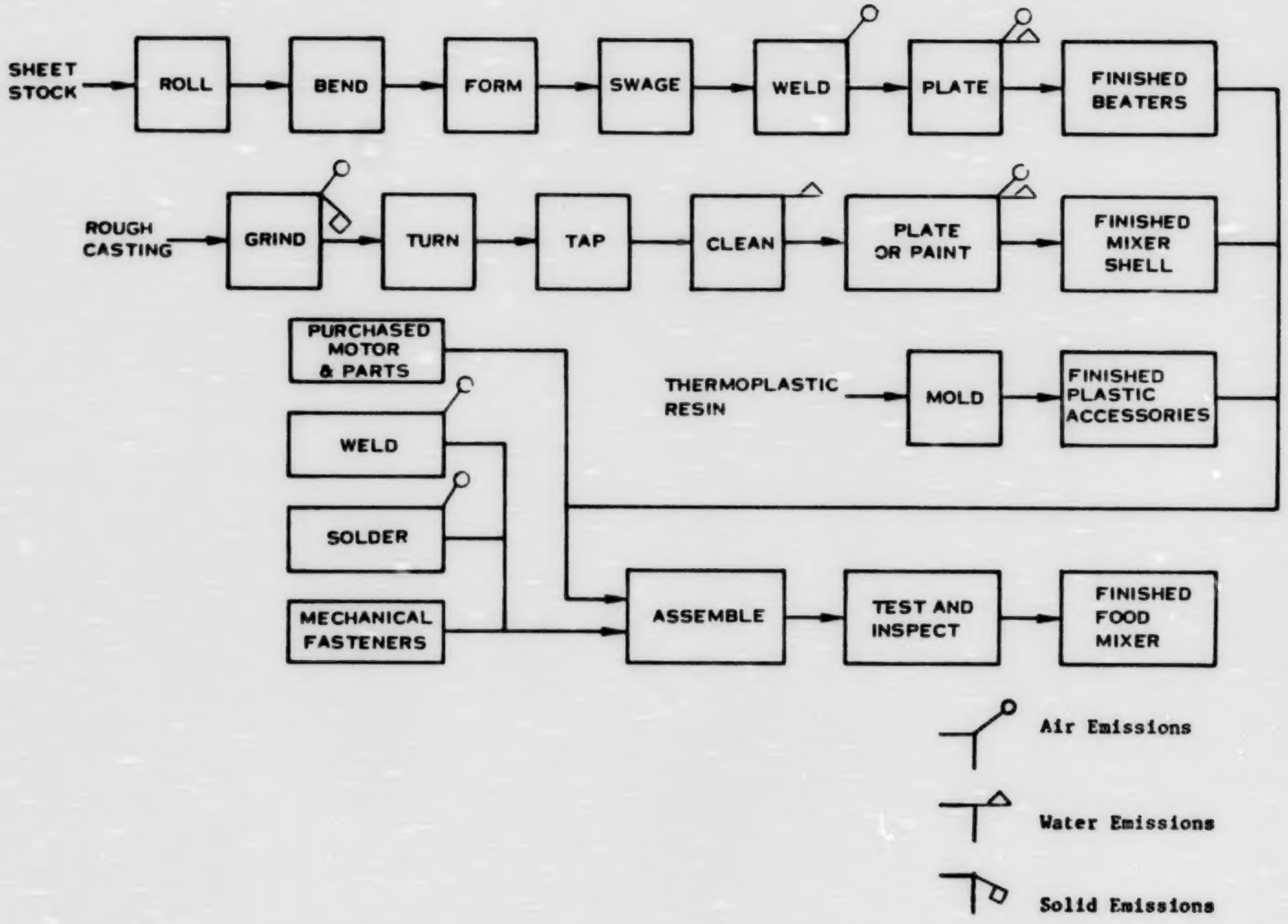
SHEET STOCK
ROLL
BEND
FORM
SWAGE
WELD
PLATE
FINISHED BEATERS
ROUGH CASTING
GRIND
TURN
TAP
CLEAN
PLATE OR PAINT
FINISHED MIXER SHELL
THERMOPLASTIC RESIN
MOLD
FINISHED PLASTIC ACCESSORIES
PURCHASED MOTOR & PARTS
WELD
SOLDER
MECHANICAL FASTENERS
ASSEMBLE
TEST AND INSPECT
FINISHED FOOD MIXER
Air Emissions
Water Emissions
Solid Emissions

FIGURE 88. FOOD MIXER MANUFACTURING.

Manufacturing Processes--

Glass and glass products are the major raw materials, with the principal manufacturing operation being mechanical material removal.

In general, electric lamps are made by drawing and forming the filament, assembling the filament to the base, and then cleaning, electroplating, and assembling the final product. The manufacture of incandescent lightbulbs (Figure 89) is representative of the electric lamp industry. The filament wire is drawn and the filament is formed and attached to a stamped base. The filament and base unit is then pickled, cleaned, rinsed, electroplated, and dried. The glass envelope is blown and then assembled to the base and filled with inert gas. The bulb is tested and packaged.

Waste Streams--

Process water is used mainly in a vapor-degreasing process following machining operations and in rinses following electroplating. Hydrofluoric acid is used to "frost" the bulbs and the exhaust gas is vented to an ammonia scrubber. The wastewater contains ammonium fluoride which is a disposal problem. Air emissions result from the vapor-degreasing and soldering operations.

Phonograph Records and Prerecorded Magnetic Tape

This industry includes establishments primarily engaged in manufacturing phonograph records and prerecorded magnetic tape. The major products are:

Master records or tapes
Phonograph record blanks
Phonograph records (including preparation of the master)
Prerecorded magnetic tape
Record blanks, phonograph
Records, phonograph.

Phonograph records and prerecorded magnetic tapes were produced by 564 plants and shipped primary products were valued at $563.9 million in 1972. Most of these plants (79 percent) employ fewer than 20 workers. About 58 percent of the products produced in this category are 45 rpm records and 41 percent are 33-1/3 rpm records. Prerecorded cartridge tapes and cassette tapes account for less than 1 percent of the total production.

Manufacturing Processes--

Plastic and magnetic tapes are the major raw materials, while the principal manufacturing operations are molding and forming (nonmetals) and chemical/electrochemical operations.

In general, phonograph records are made by molding plastic from a negative master disc. Prerecorded magnetic tapes are made by passing Mylar tape coated with iron oxide in front of a recording head.

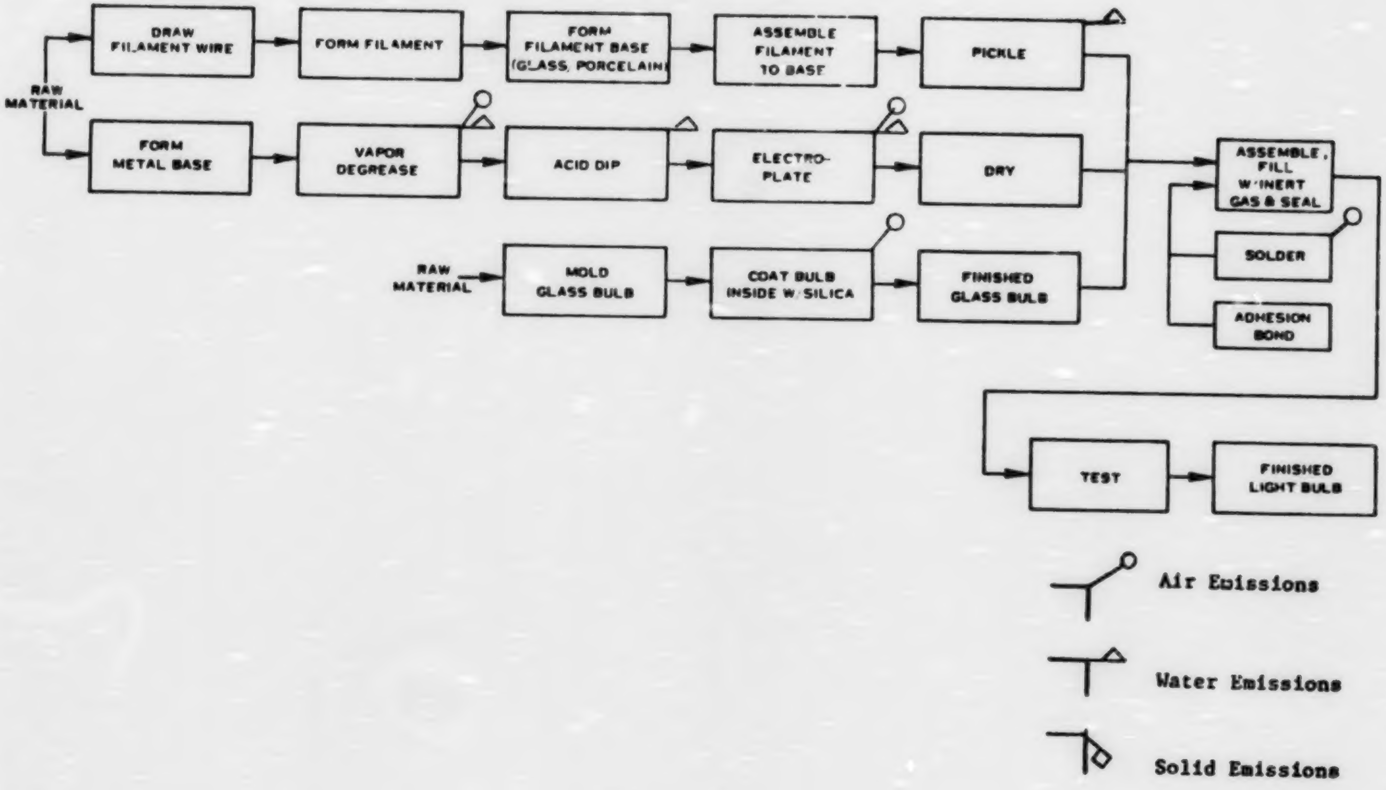
RAW MATERIAL
DRAW FILAMENT WIRE
FORM FILAMENT
FORM FILAMENT BASE (GLASS, PORCELAIN)
ASSEMBLE FILAMENT TO BASE
PICKLE
FORM METAL BASE
VAPOR DEGREASE
ACID DIP
ELECTRO-PLATE
DRY
RAW MATERIAL
MOLD GLASS BULB
COAT BULB INSIDE W/SILICA
FINISHED GLASS BULB
ASSEMBLE, FILL W/INERT GAS & SEAL
SOLDER
ADHESION BOND
TEST
FINISHED LIGHT BULB
Air Emissions
Water Emissions
Solid Emissions

FIGURE 89. INCANDESCENT LIGHT BULBS MANUFACTURING.

The manufacturing operations for fabricating phonograph records are shown in Figure 90. The first step in the manufacture of phonograph records is to machine a metal disc which serves as the master disc. Next, this disc is coated with plastic which is then grooved by the recording cutter. The disc is then coated with lacquer and a negative is made by electroforming. If this negative master is to be used to make a large quantity of records, it is made from high-grade steel. The negative master is then used as a mold in a plastic molding operation which is usually done under pressure with heat.

The plastic, if it is for low-cost records, is a synthetic thermoplastic containing fillers. High-quality records are made with vinyl plastic without filler because the fillers cause a scratching sound when played.

Pre-recorded magnetic tapes are made from thin sheets of mylar that are coated with iron oxide and slit into strips of 6.35 mm or 3.175 mm width. The magnetic tape is then wound on plastic spools. It is recorded by passing the tape at a constant speed through a recording machine. Many manufacturers of pre-recorded tape simply purchase the magnetic tape and do only the recording themselves.

Waste Streams--

Process water is used mainly for removing dust and dirt from the master disc. Air emissions result from the lacquer coating of the disc.

Telephone and Telegraph Apparatus

This industry includes establishments primarily engaged in manufacturing wire telephone and telegraph equipment, and parts especially designed for telephone and telegraph use.

Telephone and telegraph apparatus was produced by 200 plants and shipped primary products were valued at $4,531 million in 1972. Most of these plants (56 percent) employ more than 20 workers. Forty percent of the dollar value produced in this category is from telephone switching and switchboard equipment, 12 percent is from telephone carrier equipment, 40 percent is from telephone instrument sets, 7 percent is from telegraph apparatus, and 1 percent is from other equipment.

Manufacturing Processes--

Steel, wire, copper, aluminum, castings, resins, electron tubes, and semiconductors are the major raw materials. The principal manufacturing operations are mechanical material removal, material forming, material coating, chemical/electrochemical operations, physical property modification, and molding and forming (non-metals).

Telephone and telegraph equipment is made by a wide range of diverse manufacturing processes. Typically, the chassis and cabinet are manufactured and the components are installed and wired.

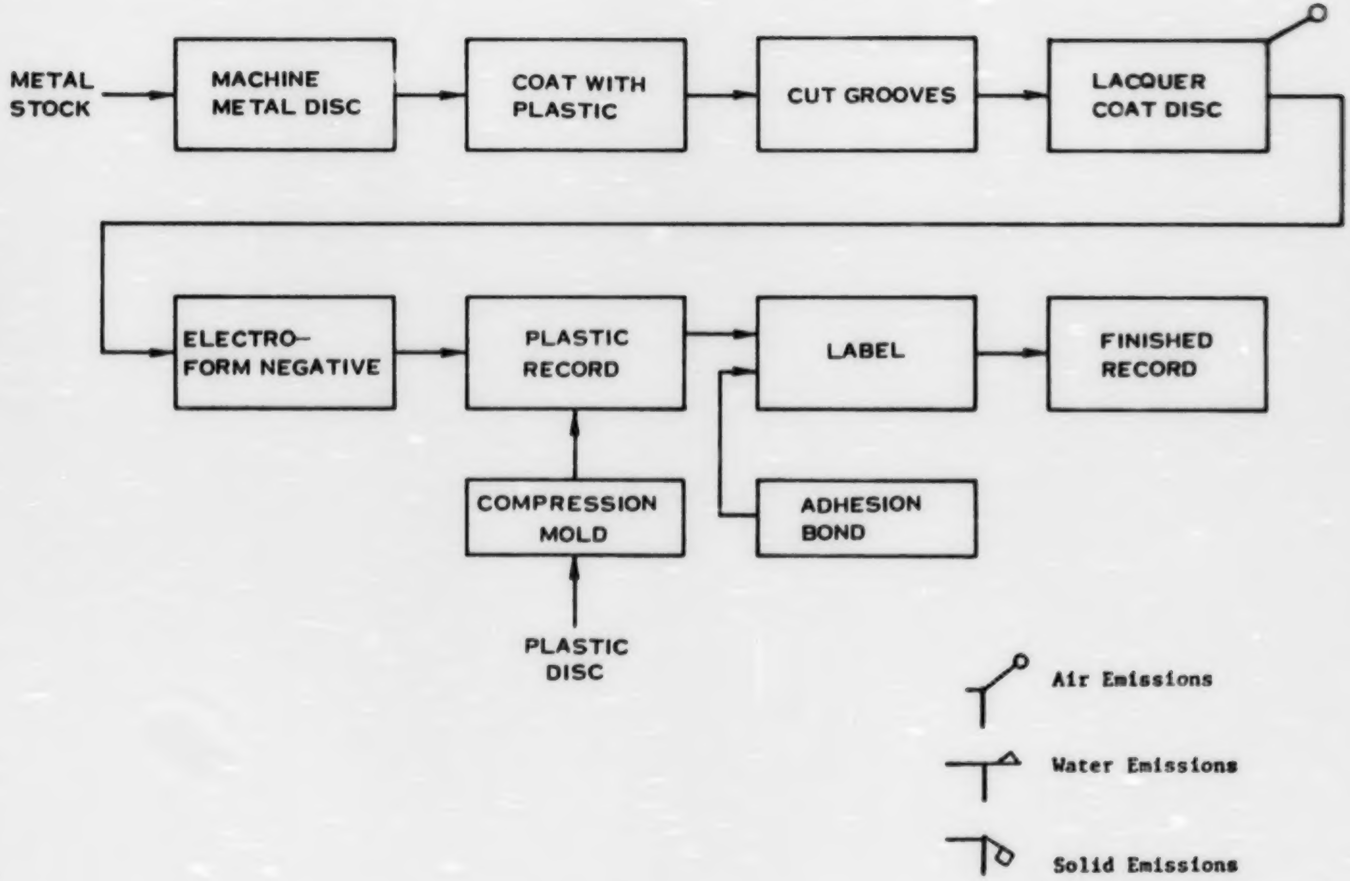
METAL STOCK
MACHINE METAL DISC
COAT WITH PLASTIC
CUT GROOVES
LACQUER COAT DISC
ELECTRO-FORM NEGATIVE
PLASTIC RECORD
LABEL
FINISHED RECORD
COMPRESSION MOLD
ADHESION BOND
PLASTIC DISC
Air Emissions
Water Emissions
Solid Emissions

FIGURE 90. PHONOGRAPH RECORD MANUFACTURING.

The manufacture of PBX (Private Branch Exchange) equipment shown in Figure 91 is representative of the telephone and telegraph industry. First the cabinet and chassis are formed by stamping, shearing, bending, spot welding, grinding, pickling, and painting. The chassis is then drilled and the components such as purchased pre-wired circuit boards, relays, and transformers are installed. These parts are assembled either by soldering or wire wrapping. Wire wrapping is now being used through the industry because of its superior mechanical and electrical properties. It is also a dry process as opposed to dip soldering.

Waste Streams--

Telephone shells are molded plastic. Process water is used mainly for electroplating, etching, painting, anodizing, cleaning, and air scrubbing. Air emissions result from the plating, painting, and grinding operations. Solid waste results from shearing, stamping, and drilling operations.

Semiconductors and Related Devices

This industry includes establishments primarily engaged in manufacturing semiconductor and related solid state devices, such as semiconductor diodes and stacks, including rectifiers, integrated microcircuits (semiconductor) networks), transistors, solar cells, and light sensing and emitting semiconductor (solid state) devices.

Semiconductors and related devices were produced by 325 plants and shipped products were valued at $2.1633 billion in 1972. Most of these plants (59 percent) employ more than 20 workers. Thirty six percent of the products produced in this category are transistors, 44 percent are diodes and rectifiers, 16 percent are integrated circuits, and 4 percent are other semiconductors.

Manufacturing Processes--

Steel insulated wire cable, aluminum, copper, castings, silicon, germanium, and resins are the major raw materials. The principal manufacturing operations are mechanical material removal, chemical/electrochemical operations, and material forming (metals).

In general, semiconductors are made from silicon or germanium wafers that are doped with impurities. These are joined together and lead wires are attached.

The manufacture of transistors (Figure 92) is representative of the semiconductors industry. (Crystals of silicon are first grown by the Czochralski or Float Zone methods. They are then cut and polished to form wafers.) The wafers are cast and sorted, then bonded together, and wires are bonded to the joined wafers. The unit is washed in ultra pure water, dried, and baked. A cap is finally soldered into place and the unit tested.

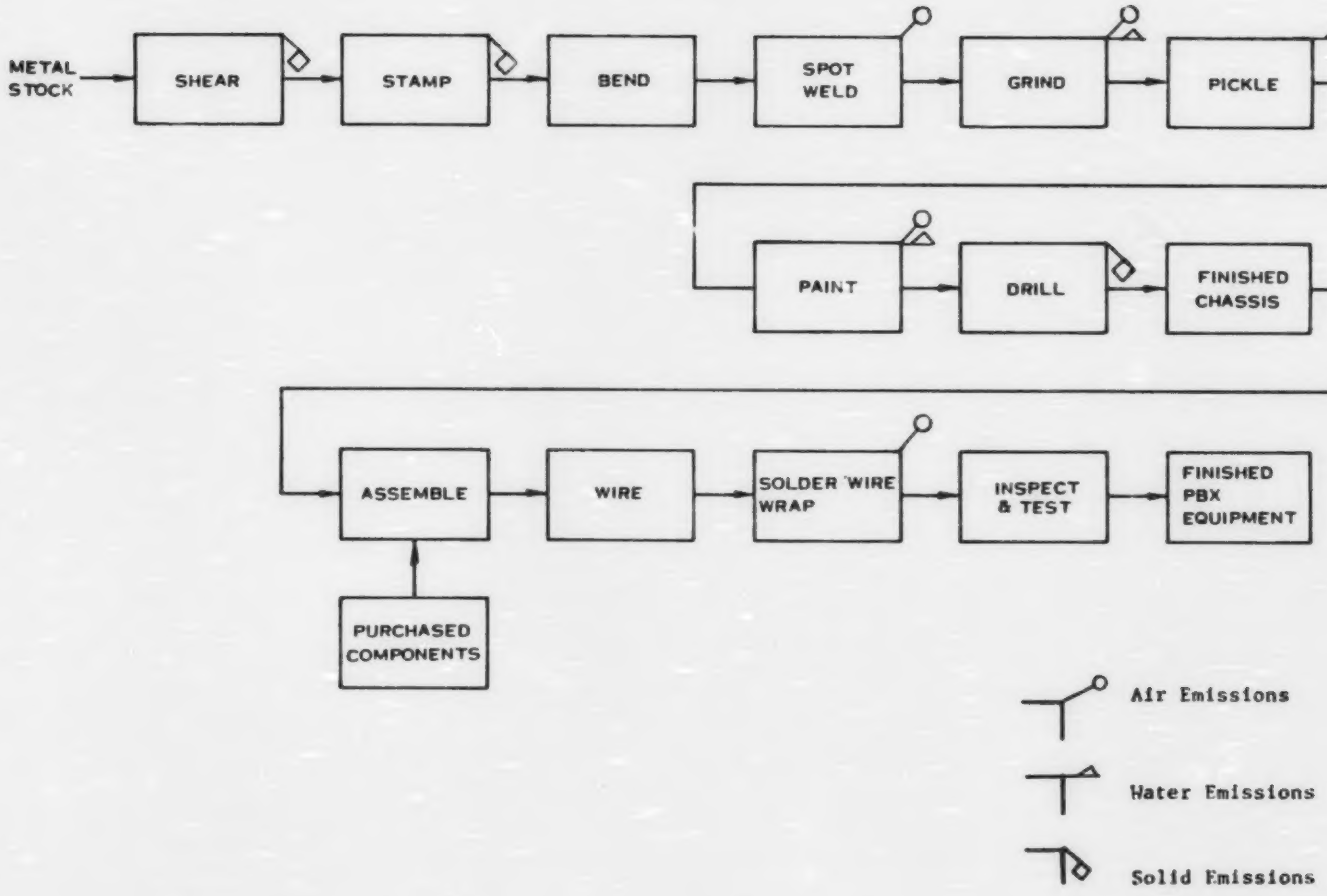
METAL STOCK
SHEAR
STAMP
BEND
SPOT WELD
GRIND
PICKLE
PAINT
DRILL
FINISHED CHASSIS
ASSEMBLE
WIRE
SOLDER 'WIRE WRAP
INSPECT & TEST
FINISHED PBX EQUIPMENT
PURCHASED COMPONENTS
Air Emissions
Water Emissions
Solid Emissions

FIGURE 91. PBX (PRIVATE BRANCH EXCHANGE) EQUIPMENT MANUFACTURING.

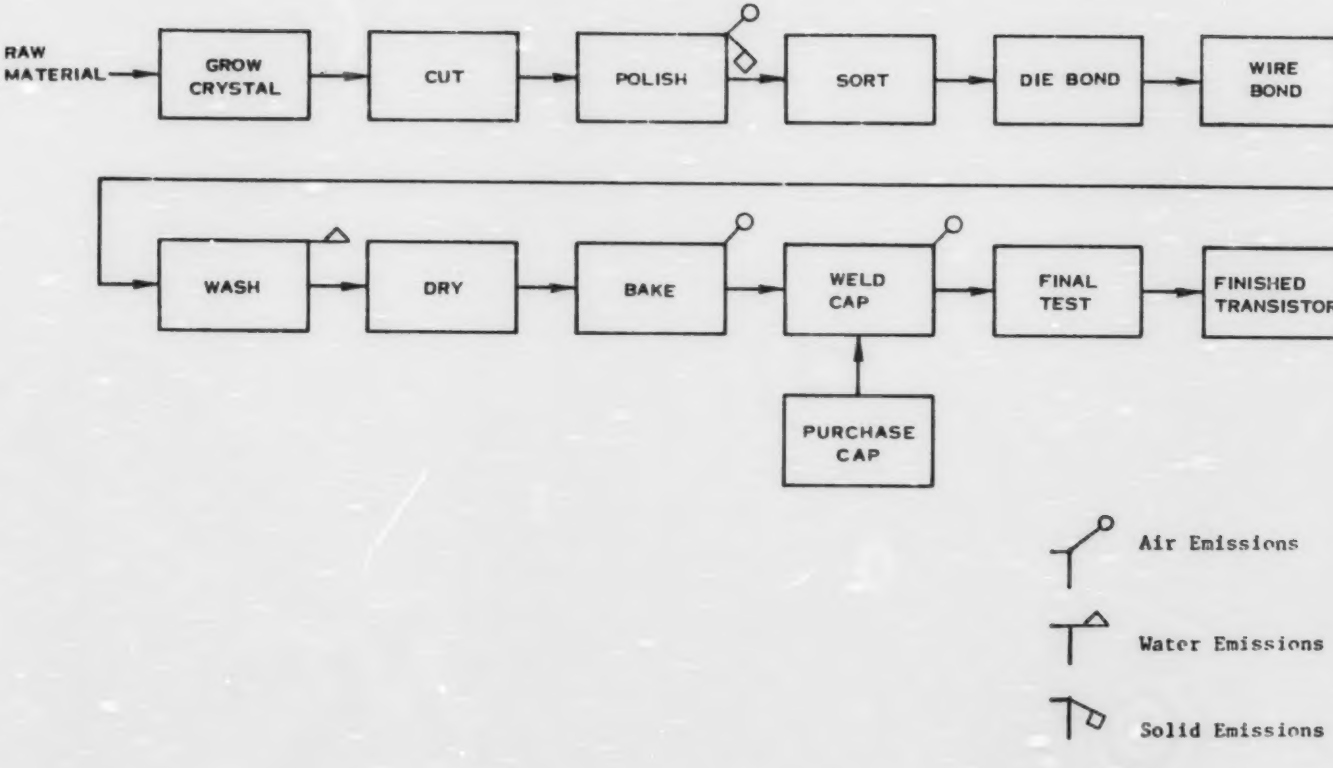
RAW MATERIAL
GROW CRYSTAL
CUT
POLISH
SORT
DIE BOND
WIRE BOND
WASH
DRY
BAKE
WELD CAP
FINAL TEST
FINISHED TRANSISTOR
PURCHASE CAP
Air Emissions
Water Emissions
Solid Emissions

FIGURE 92. TRANSISTOR MANUFACTURING.

Electronic Capacitors

This industry includes establishments primarily engaged in manufacturing electronic capacitors. The major products are:

Capacitors, electronic: fixed and variable
Condensers, for electronic end products.

Electronic capacitors were produced by 113 plants, and shipped primary products were valued at $454.4 million in 1972. Most of these plants (90 percent) employ more than 20 workers. Of the capacitors produced, 18 percent are electrolytic capacitors, 76 percent are ceramic capacitors, and 6 percent are mica capacitors.

Manufacturing Processes--

Various metal stock, wire, and dielectric materials are the major raw materials. The principal manufacturing operations are material coating, assembly operations, and physical property modification.

In general, capacitors are made by forming discs, applying a silver surface to both sides, oven drying, attaching lead wires, and plastic coating the unit.

The manufacture of ceramic disc capacitors (Figure 93) is representative of the capacitor industry. First a ceramic disc is formed and oven fired. A silver surface is applied to each side of the disc and it is oven dried. The discs are then loaded into a magazine where wires which have been previously stripped, cut, and bent are attached by dip soldering. The disc assembly is cleaned in a detergent or solvent. A plastic coating is applied and the capacitor is dried. Identification is printed on the capacitor and a wax coating is applied. The wire leads are then sheared and samples of the capacitors are tested.

Waste Streams--

Process water is used mainly for cleaning after the leads are dip soldered in place.

Storage Batteries

This segment includes establishments primarily engaged in manufacturing storage batteries, and the products include:

Alkaline cell storage batteries
Lead-acid batteries (storage batteries).

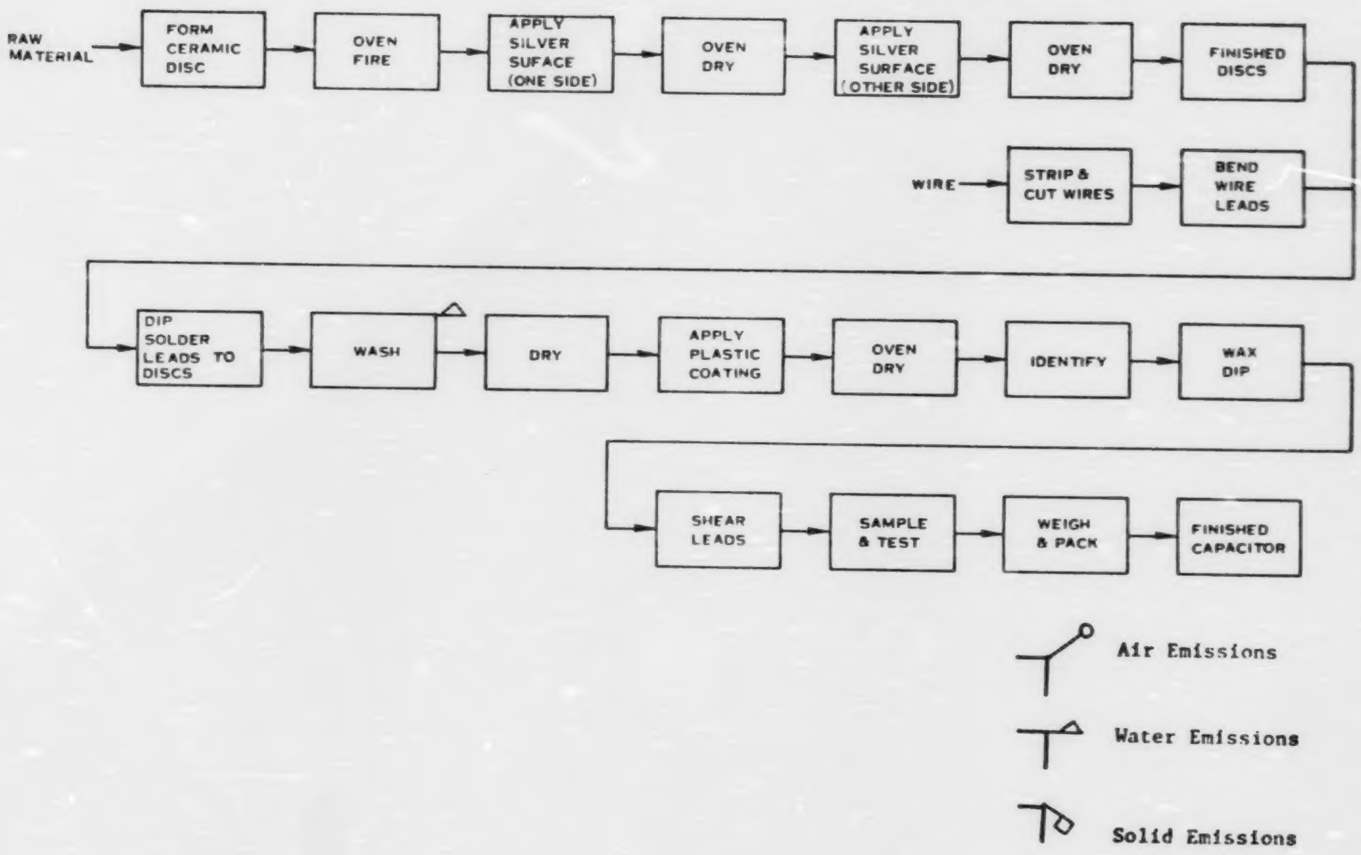
RAW MATERIAL
FORM CERAMIC DISC
OVEN FIRE
APPLY SILVER SUFACE (ONE SIDE)
OVEN DRY
APPLY SILVER SURFACE (OTHER SIDE)
OVEN DRY
FINISHED DISCS
WIRE
STRIP & CUT WIRES
BEND WIRE LEADS
DIP SOLDER LEADS TO DISCS
WASH
DRY
APPLY PLASTIC COATING
OVEN DRY
IDENTIFY
WAX DIP
SHEAR LEADS
SAMPLE & TEST
WEIGH & PACK
FINISHED CAPACITOR
Air Emissions
Water Emissions
Solid Emissions

FIGURE 93. CERAMIC DISC CAPACITOR MANUFACTURING.

Storage batteries were produced by 213 plants, and had a value for primary products shipped of $971 million in 1972. Most of these plants (56 percent) employ more than 20 workers. Seven percent of the storage batteries produced are automobile replacement batteries, 2 percent are lead-acid batteries for other than motor vehicles, and 70 percent are for other uses.

Manufacturing Processes--

Lead, purchased plastic cases, litharge, and sulfuric acid are the major raw materials. The principal manufacturing operations are molding and forming, material forming, and assembly operations.

In general, storage batteries are made by casting the plates out of lead, spreading a lead oxide and sulfuric acid paste on the plates, drying, assembling, and adding the acid.

The manufacture of lead-acid storage batteries (Figure 94) is representative of the storage battery industry. First lead is cast to form the grids. A paste is then made by mixing lead oxide with sulfuric acid and water. The paste is spread onto the lead grids to form plates which are cured and dried. The plates are stacked with a spacer material between them to form the battery cells. At this point in the assembly, the operations vary for wet-charged and dry-charged batteries. The wet-charged battery cells are assembled in a plastic or rubber case, interconnected, sealed, tested, and filled with sulfuric acid. An electrical charge is applied to the battery terminals which converts the negative plates to lead sponge and the positive plates to lead peroxide. This operation, called forming, completes the battery manufacture.

The dry-charge batteries are shipped and stored without sulfuric acid to extend the battery shelf life. For the dry-charge battery, the forming operation is accomplished by connecting the battery cells and immersing them in forming tanks containing sulfuric acid for the actual forming. The cells are then removed, washed, and assembled in the battery case. Then they are tested, decorated, and readied for shipment. Some manufacturers of dry-charged batteries are able to conduct the forming operations with the cells in the battery case.

Waste Streams--

Process water, is used mainly for cleaning and rinsing. Unused

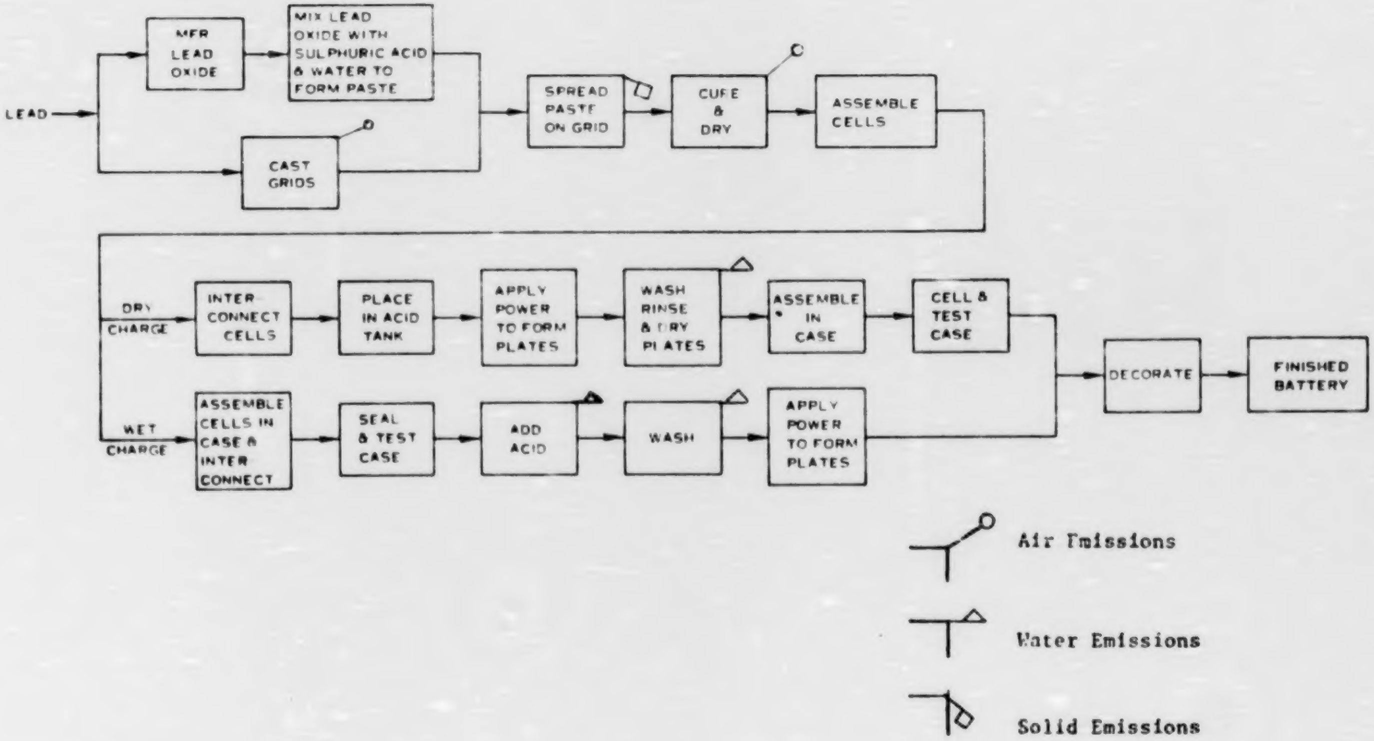
LEAD
MFR LEAD OXIDE
MIX LEAD OXIDE WITH SULPHURIC ACID & WATER TO FORM PASTE
CAST GRIDS
SPREAD PASTE ON GRID
CURE & DRY
ASSEMBLE CELLS
DRY CHARGE
INTER-CONNECT CELLS
PLACE IN ACID TANK
APPLY POWER TO FORM PLATES
WASH RINSE & DRY PLATES
ASSEMBLE IN CASE
CELL & TEST CASE
WET CHARGE
ASSEMBLE CELLS IN CASE & INTER-CONNECT
SEAL & TEST CASE
ADD ACID
WASH
APPLY POWER TO FORM PLATES
DECORATE
FINISHED BATTERY
Air Emissions
Water Emissions
Solid Emissions

FIGURE 94. LEAD-ACID STORAGE BATTERY MANUFACTURING.

sulfuric acid is a major source of waste. Wastewaters are comprised of sulfuric acid (typically 2-4%) and suspended and dissolved lead. Scrap waste from the various processes, for example, grids, paste mix, reject plates, are recovered and sent to a lead smelter for processing as secondary lead and reused.

TRANSPORTATION EQUIPMENT

This major industry includes establishments engaged in manufacturing equipment for transportation of passengers and cargo by land, air, and water. There were 8,802 establishments in 1972 primarily engaged in the manufacture of transportation equipment. They employed 1,719,000 people and shipped products valued at $94.7 billion.

Important products produced by establishments classified in this major group include motor vehicles, aircraft, guided missiles and space vehicles, ships, boats, railroad equipment, and miscellaneous transportation equipment such as motorcycles, bicycles, and snowmobiles. Thus, the manufacturing operations vary quite extensively and cannot be typified in a simple way. However, the manufacturing processes are quite similar in many respects to those discussed under fabricated metal products.

Manufacturing Processes

There are some basic processes and/or manufacturing steps which can have an impact on the environment (air, water, solids). The foundry activities of the companies in this category rank rather high in pollution potential. The many surface-finishing operations including electroplating, pickling, anodizing, painting, enameling, all have potential for contributing to an environmental impact. Lubrication of the various metal-forming and fabricating processes can contribute to problems, especially in those plants where such fabrication processes are practiced extensively. A considerable amount of plastics is used in the manufacture of both automobiles and aircraft. Waste plastics are disposed of either by burning or in the form of solid waste, which probably ends up in some landfills. Welding is a potential source of pollution in the manufacture of equipment. However, the MIG/TIG welding practices commonly used are not likely to create pollution to the extent associated with stick electrode welding used in the fabrication of larger structures. An exception to this is observed in the manufacture of ships and boats where the fumes from stick electrode welding are an even more serious problem for the welders than in field erection of towers and other large fabrications. This is due in part to the fact that the operators are more likely to be confined to smaller quarters. This is also true in the welding of tank hulls.

Motor Vehicles and Motor Vehicle Equipment--

This is by far the largest segment of the transportation equipment industry. In 1972 there were 3,391 establishments primarily engaged in the manufacture of motor vehicles, bodies for passenger cars, trucks, and buses, parts and accessories, and truck trailers. These establishments employed 807,400 people and shipped products valued at $63.9 billion. This segment included 39 percent of the establishments in the transportation equipment industry, employed 47 percent of the work force for the industry, and shipped 67 percent of the dollar value of products.

The four leading establishments engaged primarily in the manufacture of passenger automobiles are quite heavily integrated, having facilities for conducting the majority of part-making operations within one or more of their manufacturing plants. For example, General Motors has one of the largest foundries in the country and Ford has a forge shop which produced nearly 5 percent of the Nation's total output of forgings. Thus, many of the processes identified under fabricated metal products as having an impact on the environment are also represented by this industrial classification. There are, of course, several smaller firms in vehicle manufacture which purchase such components as part of their raw materials. Checker Motors, for example, purchases nearly all components except the bodies and frames, for taxicabs. The waste streams from these organizations differ in magnitude and cannot be simply classified as an industrial grouping with regard to pollution potential. Similarly, the manufacturers of truck bodies, tractors and buses all represent varying degrees of integration. Caterpillar Co., for example, has extended its integration to the manufacture of both forgings and casting while Fruehauf has largely confined its manufacturing to forming, assembling, fastening, and welding of truck bodies.

Three manufacturing processes were selected that are typical of the transportation equipment industry. Flow charts are shown for automobile manufacture and assembly (Figure 95), manufacture of automobile frames (Figure 96) and manufacture of truck trailers (Figure 97).

Waste Streams--

Table 23 shows the raw materials and operations used in manufacturing motor vehicles and equipment, the wastes engendered, and the media in which the wastes are emitted. It also shows the general levels of pollution and the current actions, if any, taken to reduce pollution.

Aircraft and Parts--

This is the second largest segment of the transportation equipment industry. In 1972 there were 1094 establishments primarily engaged in this industry. They employed 438,700 people and shipped products valued at $15.5 billion.

The major manufacturers of aircraft have concentrated their manufacturing operations on sheet metal forming, joining (riveting, welding, adhesive bonding, mechanical fastening), extensive machining, and assembly of aircraft. Virtually all subcomponents, not considered as part of the basic airframes. are purchased (engines, landing gear, drive systems, etc.). There are over 600 firms engaged in the manufacture of such components for aircraft. Furthermore, part-making firms are likely to purchase such fabricated metal products as extrusions, forgings, and castings which are then

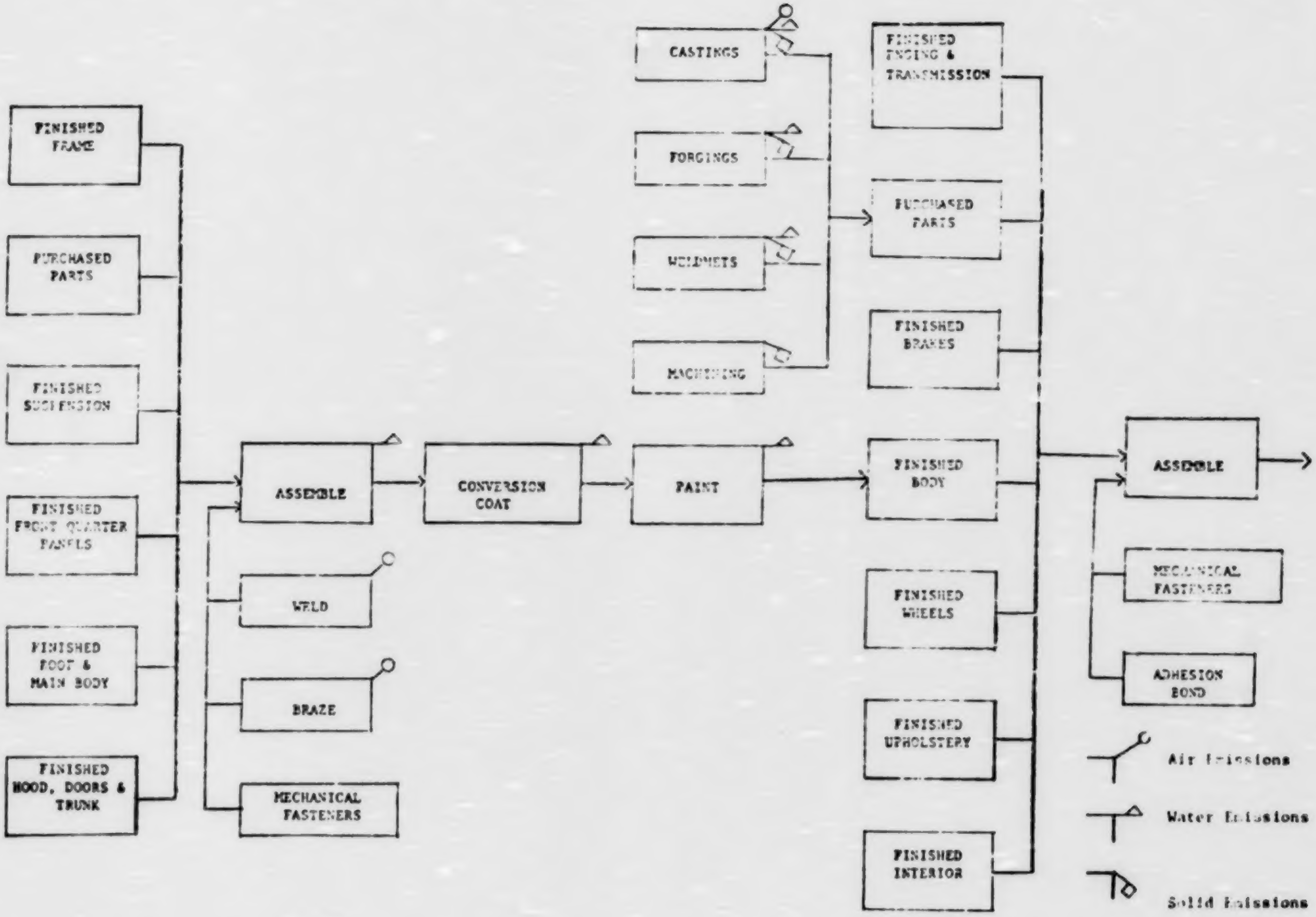
FINISHED FRAME
PURCHASED PARTS
FINISHED SUSPENSION
FINISHED FRONT QUARTER PANELS
FINISHED ROOF & MAIN BODY
FINISHED HOOD, DOORS & TRUNK
ASSEMBLE
WELD
BRAZE
MECHANICAL FASTENERS
CONVERSION COAT
PAINT
CASTINGS
FORGINGS
WELDMENTS
MACHINING
FINISHED ENGINE & TRANSMISSION
PURCHASED PARTS
FINISHED BRAKES
FINISHED BODY
FINISHED WHEELS
FINISHED UPHOLSTERY
FINISHED INTERIOR
ASSEMBLE
MECHANICAL FASTENERS
ADHESION BOND
Air Emissions
Water Emissions
Solid Emissions

FIGURE 95. AUTOMOBILE MANUFACTURE AND ASSEMBLY.

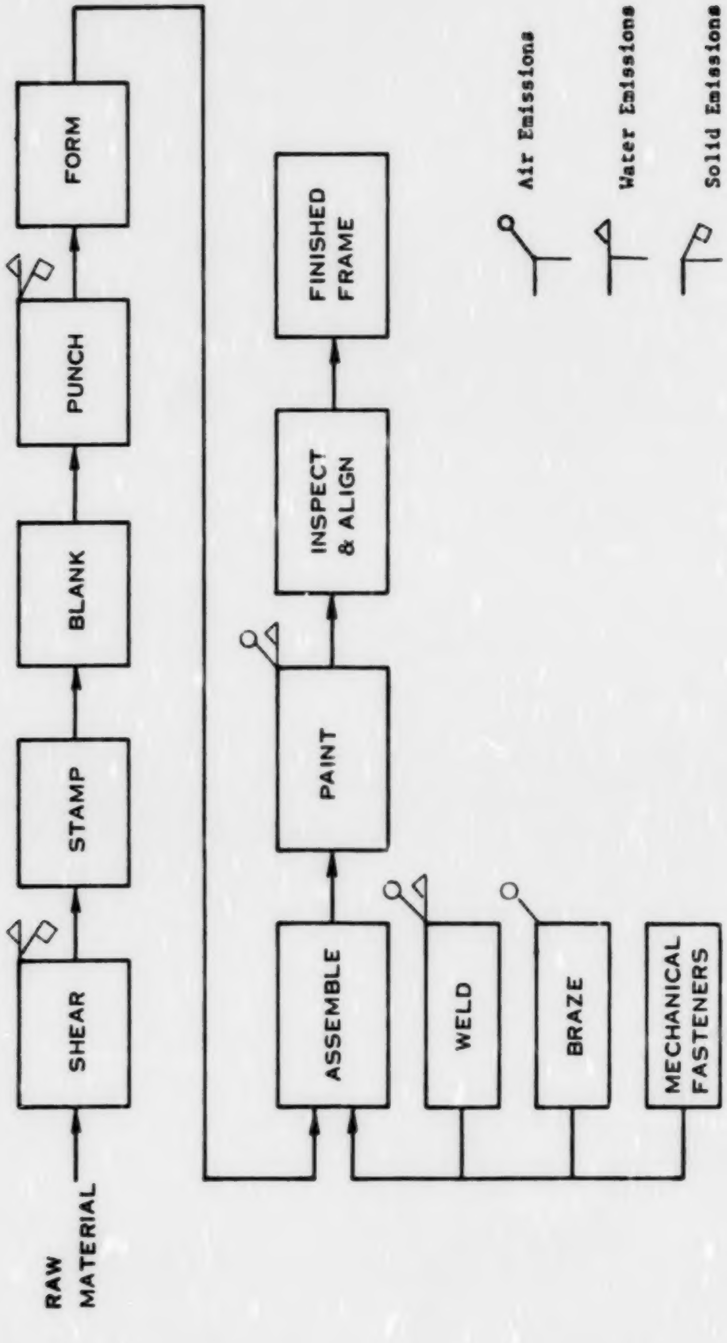
RAW MATERIAL
SHEAR
STAMP
BLANK
PUNCH
FORM
ASSEMBLE
WELD
BRAZE
MECHANICAL FASTENERS
PAINT
INSPECT & ALIGN
FINISHED FRAME
Air Emissions
Water Emissions
Solid Emissions

FIGURE 96. MANUFACTURE OF AUTOMOBILE FRAMES.

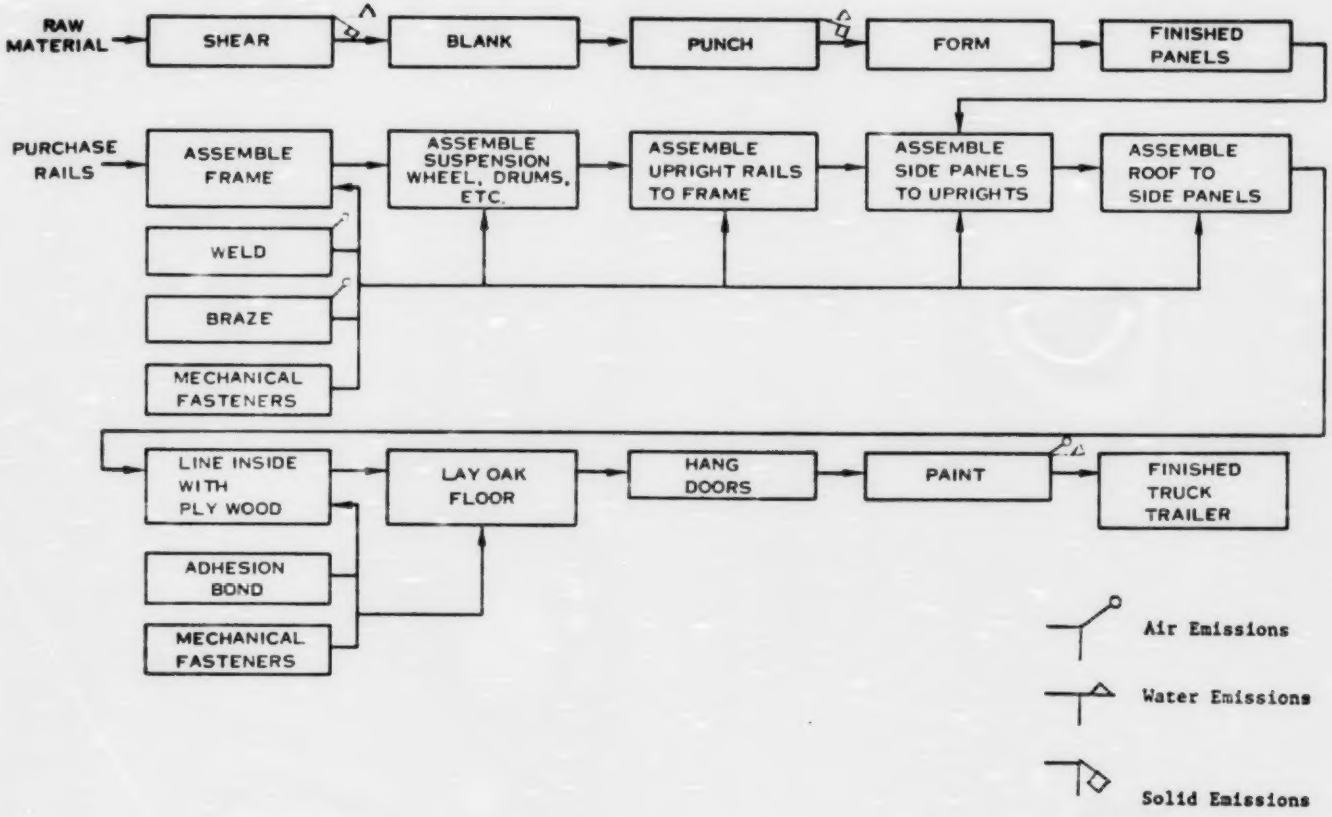
RAW MATERIAL
SHEAR
BLANK
PUNCH
FORM
FINISHED PANELS
PURCHASE RAILS
ASSEMBLE FRAME
ASSEMBLE SUSPENSION WHEEL, DRUMS, ETC.
ASSEMBLE UPRIGHT RAILS TO FRAME
ASSEMBLE SIDE PANELS TO UPRIGHTS
ASSEMBLE ROOF TO SIDE PANELS
WELD
BRAZE
MECHANICAL FASTENERS
LINE INSIDE WITH PLY WOOD
LAY OAK FLOOR
HANG DOORS
PAINT
FINISHED TRUCK TRAILER
ADHESION BOND
MECHANICAL FASTENERS
Air Emissions
Water Emissions
Solid Emissions

FIGURE 97. MANUFACTURE OF TRUCK TRAILERS.

TABLE 23. MATERIALS AND PROCESSES TYPICAL FOR MOTOR VEHICLES AND MOTOR VEHICLES EQUIPMENT.

Operations (a)	Waste/Media	Potential Levels of Pollution	Current Action
Sand casting	Fumes HC/air/water	High	Dust collection/ vent
Die casting	Fumes/air	Medium	Vent
Stamping	--	--	--
Sheet forming	--	--	--
Machining	Chips/solids	Medium	Recycle
Hot forging	Scale/solids	Medium	Land fill
Cold forging	Soaps,phosphates/water	Medium	Neutralize
Welding	Fumes/air	Locally high	Vent
Electroplating	Metallic salts /water	Medium	Neutralize
Heat treating	HC/air(b)	Low	Vent
Painting	HC/water(b)	Medium	Vent/water screen
Baking	HC/air(b)	Medium	Vent
Sanding/polishing	Solids/water	Low	Water screen
Lubricating	Oils/water	Medium to high	Separators
Pickling	Acids/alkali/water	Medium	Neutralize
Bonderizing	Acids/water	Medium	Neutralize
Assembling	Oils/water	Medium	Separators

(a) The following raw materials are used in these operations: metals (sheet, bar, wire, forging, castings, P/M parts), aluminum and alloys, copper and alloys, steel, zinc (for die casting), iron (for cast irons), chromium (plating), nickel (plating), lead (batteries), fasteners, metal powders, solder, cloth/fabric, plastics/glass, wood, acids/alkali, oils, greases, resins/adhesives, solvents/paints, rubber products, and freon.

(b) HC = hydrocarbon.

machined and assembled into the subcomponents. Figure 98 shows a general flow chart for airplane manufacturing.

Waste Streams--

The very nature of aircraft and parts manufacture is such that very little solid nonrecyclable waste is formed during the manufacturing operations. On the other hand, the use of composites, plastics, and fabrics can result in potential environmental impact if such materials are not properly disposed of. Such materials can form noxious fumes if disposed of by burning. The extensive machining operations usually associated with aircraft manufacture are the sources of water-soluble cutting oils which are often disposed of in the local sewage systems. Depending on the levels of use, this can have an environmental impact. Other than the fumes formed during welding and the vapors coming from the painting operations, there are few sources of air pollutants associated with the manufactures of aircraft. Table 24 summarizes these wastes and their approximate levels.

Ship and Boat Building and Repairing--

This is a medium-size segment of the transportation equipment industry. In 1972 there were 2,232 establishments primarily engaged in building and repairing boats and ships of all varieties, including barges, dredges, drilling platforms, and floating drydocks as well as more conventional vessels. These establishments employed 185,200 people and shipped products valued at $4.3 billion.

Figure 99 shows a general flow chart for the manufacture of steel vessels. The production of glass-fiber-reinforced boats is significantly different, and is shown in Figure 100.

Waste Streams--

From the standpoint of environmental impact, perhaps the most noticeable operations associated with manufacture of large steel ships are the extensive torch cutting and welding operations that are used to cut the large plates to size and for subsequently joining them to the frames and bulkheads. Riveting is extensively used, but the major source of pollution from this process is in the heating of the rivets, and the extent depends on the types of furnaces being used for the purpose. Painting is also extensively used during and after assembly. Scrap steel makes up the majority of waste originating from shipbuilding operations.

By contrast, the manufacture of fiber-glass boats is a relatively clean operation involving mostly layup and curing of the resins used in the joining of layers and sections of both the skins and bulkheads. Disposal of the waste resins can represent an environmental impact if they are burned.

Table 25 summarizes the waste streams from both types of operations.

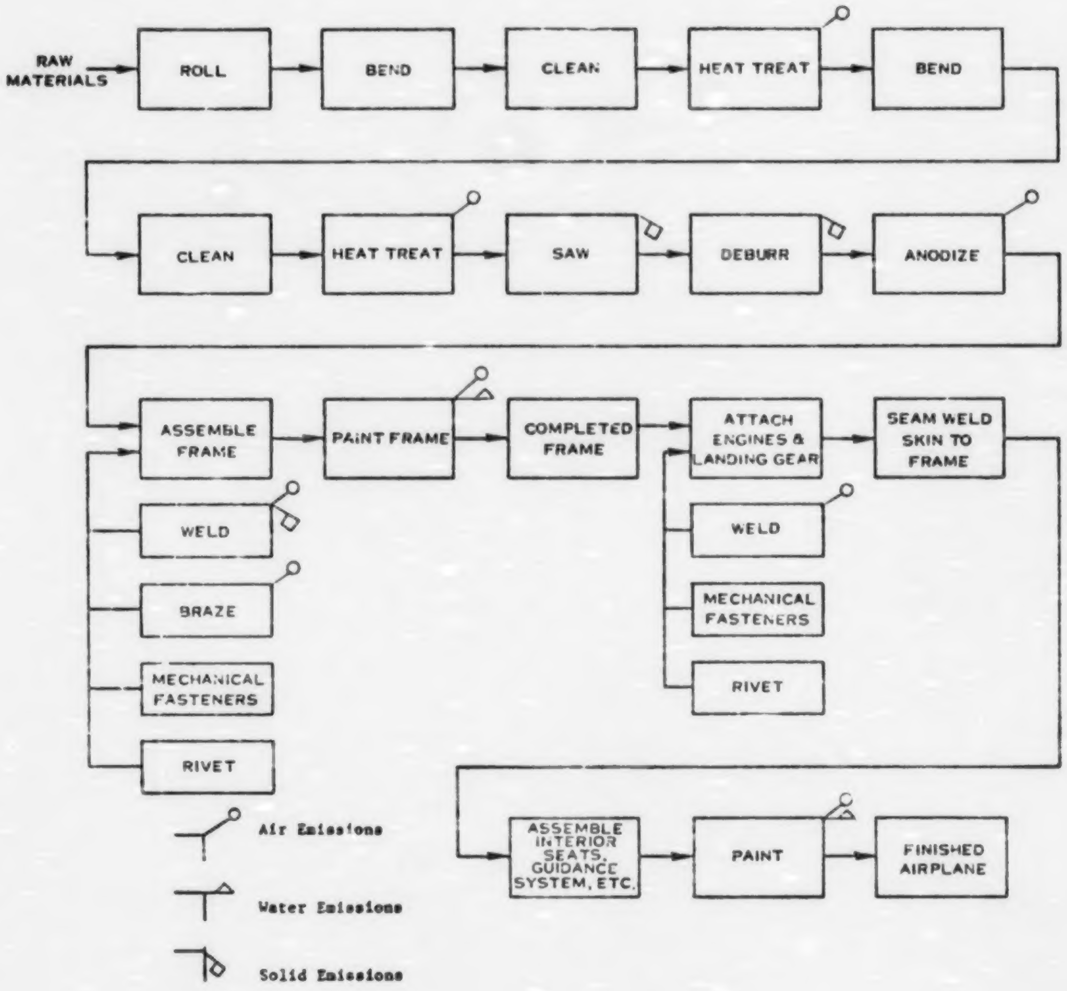
RAW MATERIALS
ROLL
BEND
CLEAN
HEAT TREAT
BEND
CLEAN
HEAT TREAT
SAW
DEBURR
ANODIZE
ASSEMBLE FRAME
WELD
BRAZE
MECHANICAL FASTENERS
RIVET
PAINT FRAME
COMPLETED FRAME
ATTACH ENGINES & LANDING GEAR
WELD
MECHANICAL FASTENERS
RIVET
SEAM WELD SKIN TO FRAME
ASSEMBLE INTERIOR SEATS, GUIDANCE SYSTEM, ETC.
PAINT
FINISHED AIRPLANE
Air Emissions
Water Emissions
Solid Emissions

FIGURE 98. MANUFACTURE OF AIRCRAFT.

TABLE 24. MATERIALS AND PROCESSES TYPICAL FOR AIRCRAFT AND PARTS.

Operations[a]	Waste/Media	Potential Levels of Pollution	Current Action
Forming	Lubricants/water	Low	--
Riveting	--	--	--
Bonding	HC/water, air[b]	Low	Vent
Welding	Fumes/air	Low	Vent
Electroplating	Metal salts/water	Low	--
Heat treating	Fumes/air	Low	Vent
Lubricating	Oils/water	Medium	Separation
Anodizing	Chemicals/water	Low	Neutralize
Pickling	Acids/water	Low	Neutralize
Chemical machining	Acids/water	Medium	Neutralize
Sanding/polishing	Dusts, metal fines/ water, solids	Low	-- --
Machining	Chips/solid	Medium	Recycle
Grinding	Dust/water, solids	Low	--
Painting	HC/air, water[b]	Medium	Vent
Baking	HC/air[b]	Medium	Vent
Electrodischarge machinery	Metallic fines/solids	Medium	Settling tanks
Assembling	Oils/water	Low	Sewage

(a) The following raw materials are used in these operations: metals (sheet, bar, wire, forging, casting, extrusion), aluminum alloys, copper and alloys, steels, titanium alloys, heat-resistant alloys, magnesium alloys, nickel (plating), chromium (plating), glass, plastics, resins, fiberglass, solvents, rubber products, paints, oils, greases, cloth/fabric propellants, and acids/alkali.

(b) HC = hydrocarbon.

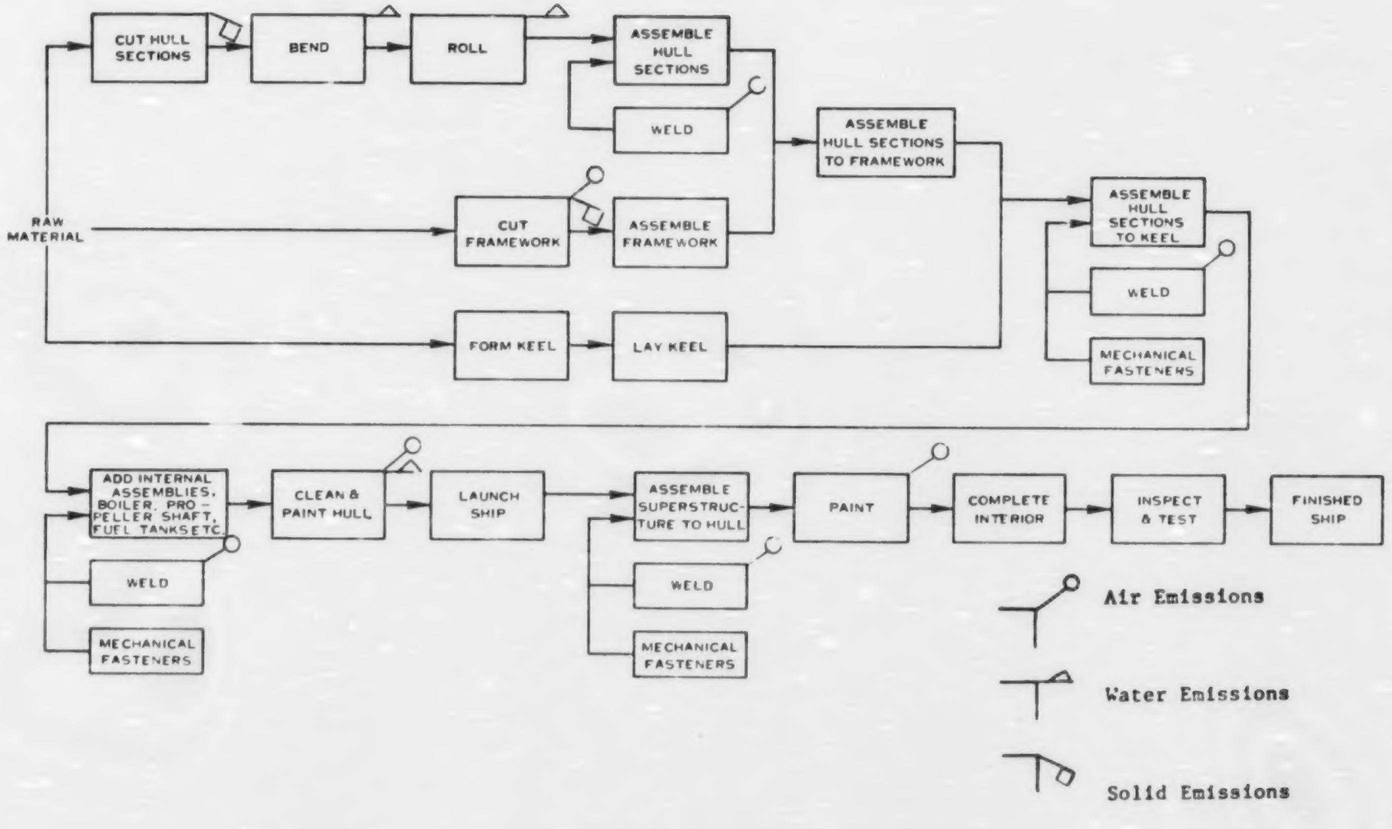
RAW MATERIAL
CUT HULL SECTIONS
BEND
ROLL
ASSEMBLE HULL SECTIONS
WELD
CUT FRAMEWORK
ASSEMBLE FRAMEWORK
FORM KEEL
LAY KEEL
ASSEMBLE HULL SECTIONS TO FRAMEWORK
ASSEMBLE HULL SECTIONS TO KEEL
WELD
MECHANICAL FASTENERS
ADD INTERNAL ASSEMBLIES, BOILER, PROPELLER SHAFT, FUEL TANKS ETC.
WELD
MECHANICAL FASTENERS
CLEAN & PAINT HULL
LAUNCH SHIP
ASSEMBLE SUPERSTRUCTURE TO HULL
WELD
MECHANICAL FASTENERS
PAINT
COMPLETE INTERIOR
INSPECT & TEST
FINISHED SHIP
Air Emissions
Water Emissions
Solid Emissions

FIGURE 99. MANUFACTURE OF SHIPS.

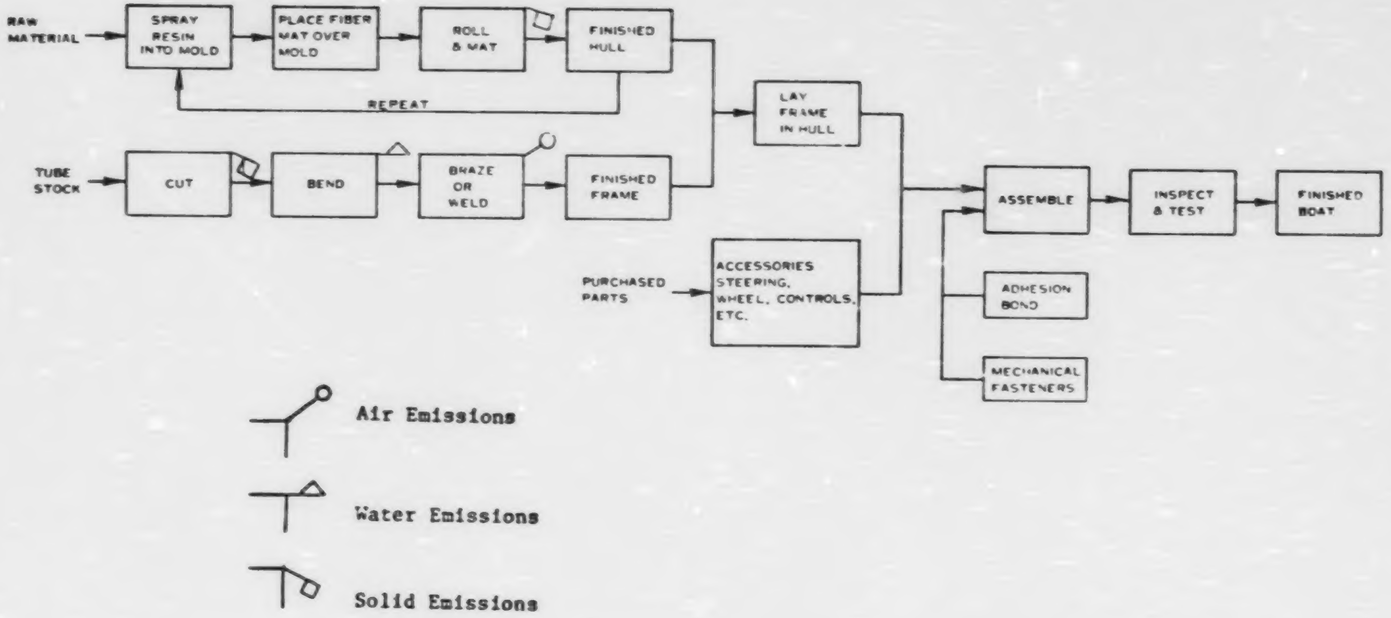
RAW MATERIAL
SPRAY RESIN INTO MOLD
PLACE FIBER MAT OVER MOLD
ROLL & MAT
FINISHED HULL
REPEAT
TUBE STOCK
CUT
BEND
BRAZE OR WELD
FINISHED FRAME
LAY FRAME IN HULL
PURCHASED PARTS
ACCESSORIES STEERING, WHEEL, CONTROLS, ETC.
ASSEMBLE
ADHESION BOND
MECHANICAL FASTENERS
INSPECT & TEST
FINISHED BOAT
Air Emissions
Water Emissions
Solid Emissions

FIGURE 100. MANUFACTURE OF FIBERGLASS BOATS.

TABLE 25. MATERIALS AND PROCESSES TYPICAL FOR SHIP AND BOAT BUILDING AND REPAIRING

Operations[a]	Waste/Media	Potential Levels of Pollution	Current Action
Plate forming	Oils/water	Low	Runoff
Welding	Fumes/air	High/local	Vent/masks
Riveting	--	--	--
Mechanical fastening	--	--	--
Torch cutting	Fumes,dust/air,solids	Medium/local	Masks,vent
Molding of plastics	Fumes/air	--	--
Sand blasting	Dust/air,solid	--	--
Fabrication	Oils/water Scrap/solids	Medium --	Runoff recycle
Adhesive joining	--	Low	--
Machining	Solid chips	Medium	Recycle

(a) The following raw materials are used in these operations: metals (castings, forgings, plate, sheet, bar wire, extrusion) steels, aluminum alloys, nickel alloys, copper alloys, welding rod/flux, plastics, rope, wood, plywood, resins, rubber, fiberglass, epoxies, plexiglass, glass, motors, diesel, gasoline, and electric.

Railroad Equipment--

This is a small segment of the transportation equipment industry, accounting for only about 3 percent of both employment and value of shipments. In 1972 there were 163 establishments primarily engaged in manufacturing railroad equipment. They employed 50,800 people and shipped products valued at $2.446 billion. If coal is to fulfill its projected role in the U.S. energy picture by 1985, the manufacture of railroad equipment must be greatly increased.

Figure 101 shows a general flow chart for the manufacture of railroad locomotives.

Waste Streams--

In many respects the manufacture of railroad equipment has much in common with the manufacture of trucks from the environmental standpoint, in that both types of manufacturers usually purchase most of the components and assemble them by riveting, welding, and mechanical fastening. The welding operations stand out as a major factor as do the painting operations. Waste products include scrap metal and various forms of runoff from rinsing, pickling,and painting operations. Table 26 summarizes the waste streams from this type of operation.

Motorcycles, Bicycles, and Parts--

This is a very small segment of the U.S. transportation equipment industry, accounting for only about 1 percent each of employment and value of shipments for the entire industry. There were 222 establishments in the United States in 1972 primarily engaged in manufacturing motorcycles, bicycles, and parts. They employed 17,600 people and shipped products valued at $660 million.

This U.S. manufacturing industry produces only a fraction of the motorcycles, bicycles, and parts that are purchased in the United States. Most motorcycles are imported, as are most expensive, lightweight bicycles. Also, many parts are imported for bicycles that are assembled in the United States.

Figure 102 shows a general flow chart for the production of bicycles, which represent over 90 percent of the products produced by this industry.

Waste Streams--

The environmental impacts of the manufacturing steps involved are relatively low with the possible exception of the painting operation where the overspray is relatively high for tubular frames (in comparison with the painting of products having sheet metal construction.) Welding and brazing are processes which have a modest impact on the environment. Otherwise the manufacture of bicycles and parts can be considered to have little impact on the environment. Table 27 shows this clearly.

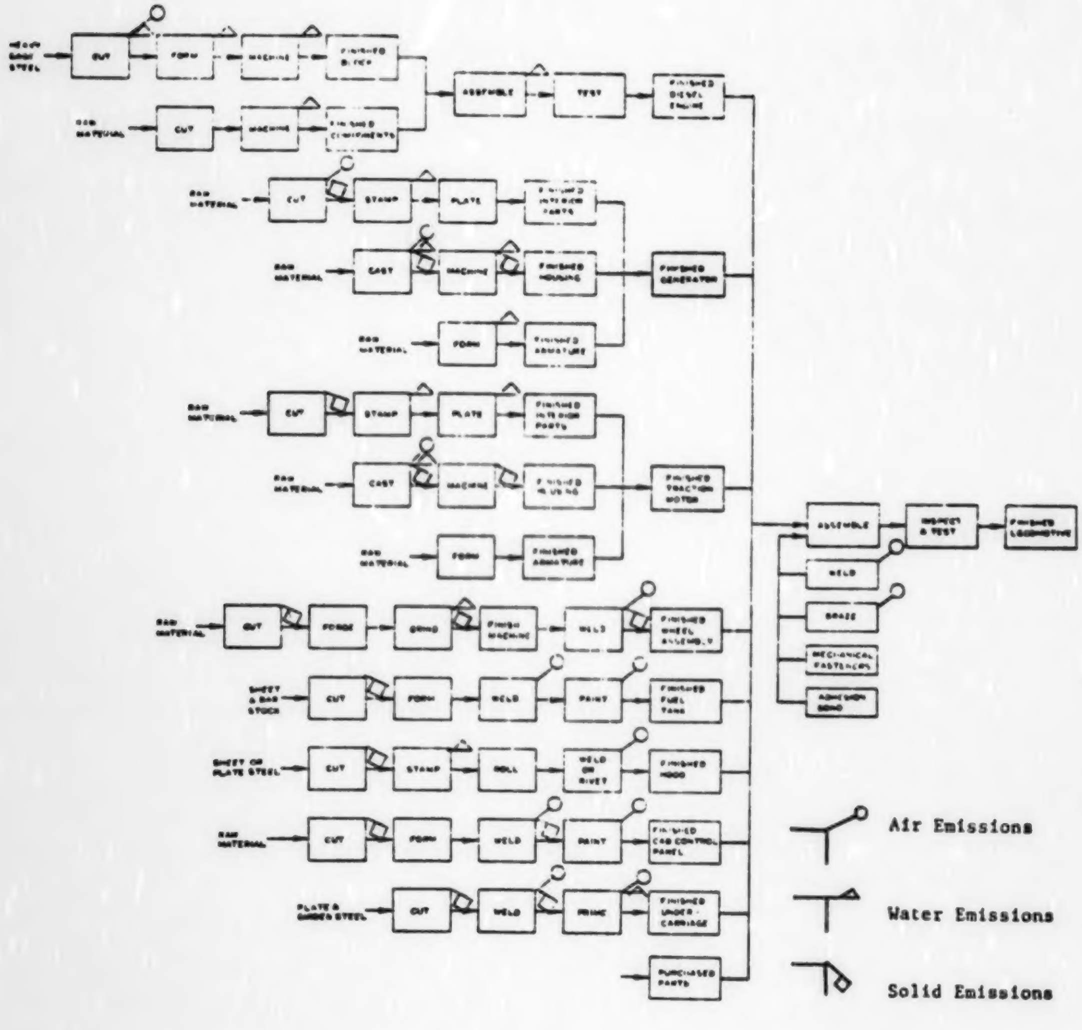
HEAVY BAR STEEL
CUT
FORM
MACHINE
FINISHED BLOCK
RAW MATERIAL
CUT
MACHINE
FINISHED COMPONENTS
ASSEMBLE
TEST
FINISHED DIESEL ENGINE
RAW MATERIAL
CUT
STAMP
PLATE
FINISHED INTERIOR PARTS
RAW MATERIAL
CAST
MACHINE
FINISHED HOUSING
FINISHED GENERATOR
RAW MATERIAL
FORM
FINISHED ARMATURE
RAW MATERIAL
CUT
STAMP
PLATE
FINISHED INTERIOR PARTS
RAW MATERIAL
CAST
MACHINE
FINISHED HOUSING
FINISHED TRACTION MOTOR
RAW MATERIAL
FORM
FINISHED ARMATURE
ASSEMBLE
INSPECT & TEST
FINISHED LOCOMOTIVE
WELD
BRAZE
MECHANICAL FASTENERS
ADHESION BOND
RAW MATERIAL
CUT
FORGE
GRIND
FINISH MACHINE
WELD
FINISHED WHEEL ASSEMBLY
SHEET & BAR STOCK
CUT
FORM
WELD
PAINT
FINISHED FUEL TANK
SHEET OR PLATE STEEL
CUT
STAMP
ROLL
WELD OR RIVET
FINISHED HOOD
RAW MATERIAL
CUT
FORM
WELD
PAINT
FINISHED CAB CONTROL PANEL
PLATE & GIRDER STEEL
CUT
WELD
PRIME
FINISHED UNDER-CARRIAGE
PURCHASED PARTS
Air Emissions
Water Emissions
Solid Emissions

FIGURE 101. MANUFACTURE OF RAILROAD LOCOMOTIVES.

TABLE 26. MATERIALS AND PROCESSES TYPICAL FOR RAILROAD EQUIPMENT.

Operations[a]	**Waste/Media**	**Potential Levels of Pollution**	**Current Action**
Welding	Fumes/air	Medium/local	Vent
Forging(wheels)	Smoke,scale/air, solids	Medium	Vent
Casting	Fumes,dust/air,water, solids	High	Filters
Machining	Oils/water	Medium	--
Wire winding	--	Low	--
Sheet forming	Oils/water	Low	--
Torch cutting	Vapor,slags/air,solids	Medium/local	Vent
Machining	Chips/solid	Medium	Recycle
Assembling	--	--	--
Painting	Overspray/water,air	--	--
Lubricating	Oils/water	Medium	--
Pickling	Spent liquors/water	Medium	--
Sandblasting	Solids	Medium/local	--

(a) The following raw materials are used in these operations: metals (plate, sheet, forgings, castings, bar, wire), steel, aluminum, copper, iron (castings), brazing alloys, solder, wood, plastic, acids/alkali, oils, greases, paints, and solvents.

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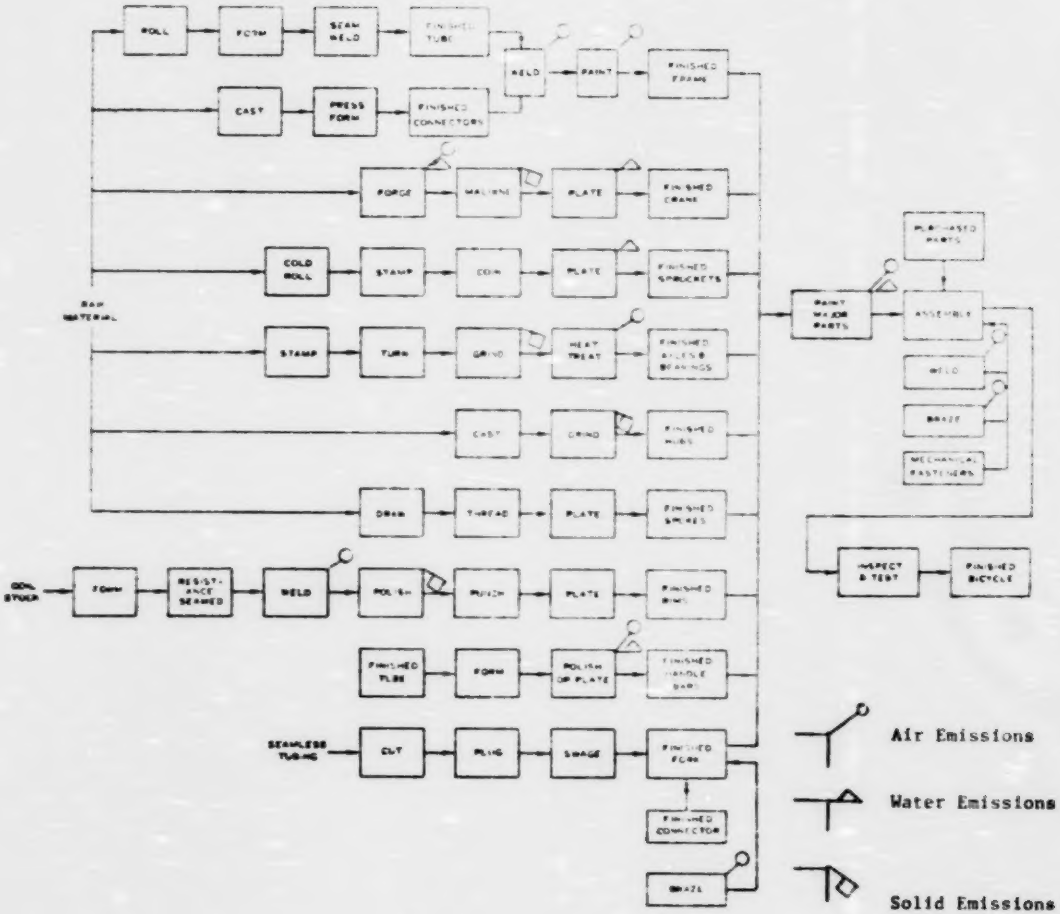

RAW MATERIAL
ROLL
FORM
SEAM WELD
FINISHED TUBE
CAST
PRESS FORM
FINISHED CONNECTORS
WELD
PAINT
FINISHED FRAME
FORGE
MACHINE
PLATE
FINISHED CRANK
COLD ROLL
STAMP
COIN
PLATE
FINISHED SPROCKETS
STAMP
TURN
GRIND
HEAT TREAT
FINISHED AXLES & BEARINGS
CAST
GRIND
FINISHED HUBS
DRAW
THREAD
PLATE
FINISHED SPOKES
COIL STOCK
FORM
RESIST-ANCE SEAMED
WELD
POLISH
PUNCH
PLATE
FINISHED RIMS
FINISHED TUBE
FORM
POLISH OR PLATE
FINISHED HANDLE BARS
SEAMLESS TUBING
CUT
PLUG
SWAGE
FINISHED FORK
FINISHED CONNECTOR
BRAZE
PAINT MAJOR PARTS
PURCHASED PARTS
ASSEMBLE
WELD
BRAZE
MECHANICAL FASTENERS
INSPECT & TEST
FINISHED BICYCLE
Air Emissions
Water Emissions
Solid Emissions

FIGURE 102. MANUFACTURE OF BICYCLES.

TABLE 27. MATERIALS AND PROCESSES TYPICAL FOR MOTORCYCLES, BICYCLES, AND PARTS.

Operations [a]	Waste/Media	Potential Levels of Pollution	Current Action
Roll forming	Oil	Low	--
Welding	Fumes/air	Medium/local	Vent
Stamping	Trimmings/solids	Low	Recycle
Machining	Chips/solids	Low	Recycle
Electroplating	Metal salts/water	Low	Neutralize
Acid pickling	Liquors/water	Low	Neutralize
Polishing	Dust/air,solid		
Heat treating	HC/air [b]	Low	--
Painting	HC/air,water [b]	Medium	Water curtain
Lubricating	HC/air,water [b]	Low	--
Assembling	Oil/water	Low	--

(a) The following raw materials are used in these operations: metals (strip, tubing bar, castings stampings, forgings, steel, aluminum alloys, brass, brazing alloys), rubber products, paint, acids, oils, greases, leather, batteries, and motors.

(b) HC = hydrocarbon.

Guided Missiles and Space Vehicles and Parts--

This is a medium-size segment of the transportation equipment industry. There were 147 establishments primarily engaged in this industry segment in 1972. They employed 160,100 people and shipped products valued at $5.628 billion.

Figure 103 shows a general flow chart for the manufacture of guided missiles. The nose cone is an integral part of every missile system, and Figure 104 shows a flow chart for production of nose cones.

Waste Streams--

This grouping can be considered to have impact on the environment similar to the aircraft industry, except where the propellants represent potential pollution problems. This is especially true when the missiles are dismantled and either replaced or refueled. The manufacturing processes which stand out as contributing to environmental problems include the machining, lubricating of materials during metal forming processes, and welding. The welding processes used, however, are not nearly as serious as the stick electrode welding used in some other industries.

Table 28 summarizes the waste streams from manufacturing guided missiles, space vehicles and parts.

Miscellaneous Transportation Equipment--

This catch-all grouping of transportation equipment includes such disparate products as travel trailers and campers, military tanks and components, electric golf carts, all-terrain vehicles, snowmobiles, pushcarts, wheelbarrows, midget autos (power driven), go-carts, and utility automobile trailers and chassis.

This small segment of the transportation equipment industry is characterized by a rather large number of fairly small establishments. In 1972 there were 1,553 establishments primarily engaged in manufacturing miscellaneous transportation equipment. These establishments employed 59,100 people and shipped products valued at $2.269 billion.

Figure 105 shows a flow chart for the production of military tanks.

Waste Streams--

The manufacturing processes most likely to have a significant impact on the environment are the welding and painting of tank components and assemblies. The other manufacturing processes and environmental impacts compare with those for the manufacturing of trucks and buses. Table 29 summarizes the waste streams from the production of miscellaneous transportation equipment.

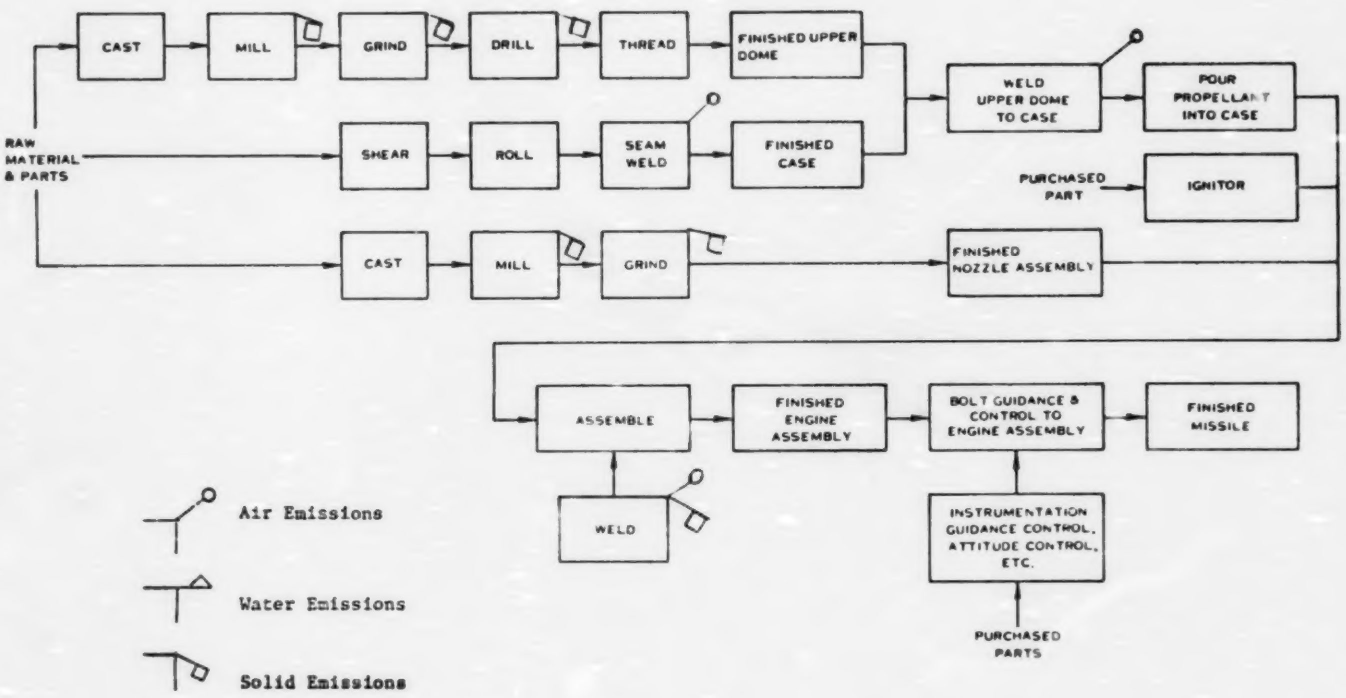

RAW MATERIAL & PARTS
CAST
MILL
GRIND
DRILL
THREAD
FINISHED UPPER DOME
SHEAR
ROLL
SEAM WELD
FINISHED CASE
CAST
MILL
GRIND
WELD UPPER DOME TO CASE
POUR PROPELLANT INTO CASE
PURCHASED PART
IGNITOR
FINISHED NOZZLE ASSEMBLY
ASSEMBLE
WELD
FINISHED ENGINE ASSEMBLY
BOLT GUIDANCE & CONTROL TO ENGINE ASSEMBLY
INSTRUMENTATION GUIDANCE CONTROL, ATTITUDE CONTROL, ETC.
PURCHASED PARTS
FINISHED MISSILE
Air Emissions
Water Emissions
Solid Emissions

FIGURE 103. MANUFACTURE OF MISSILES.

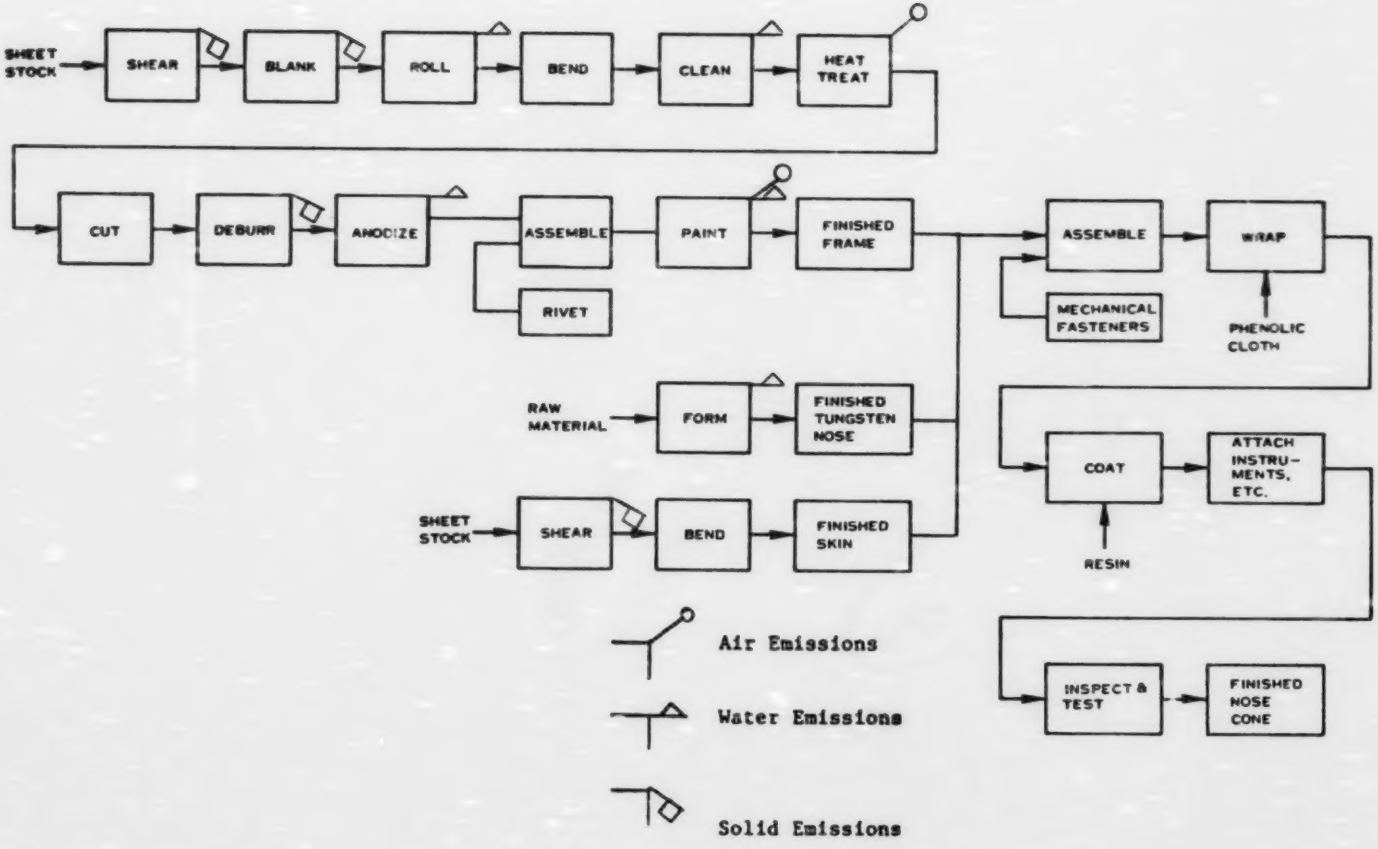

SHEET STOCK
SHEAR
BLANK
ROLL
BEND
CLEAN
HEAT TREAT
CUT
DEBURR
ANODIZE
ASSEMBLE
RIVET
PAINT
FINISHED FRAME
RAW MATERIAL
FORM
FINISHED TUNGSTEN NOSE
SHEET STOCK
SHEAR
BEND
FINISHED SKIN
ASSEMBLE
MECHANICAL FASTENERS
WRAP
PHENOLIC CLOTH
COAT
RESIN
ATTACH INSTRU-MENTS, ETC.
INSPECT & TEST
FINISHED NOSE CONE
Air Emissions
Water Emissions
Solid Emissions

FIGURE 104. MANUFACTURE OF MISSILE NOSE CONES.

TABLE 28. MATERIALS AND PROCESSES TYPICAL FOR GUIDED MISSILES AND SPACE VEHICLES AND PARTS.

Operations[a]	Waste/Media	Potential Levels of Pollution	Current Action
Sheet forming	Oil/water	Low	--
Machining	Chips/solid	Medium	Recycle chips
Electrochemical machining	Metallic fines	Low	--
Material molding	fumes,slag/air,solid	Medium	Vent
Anodizing	Acids/water	Medium	Neutralize
Pickling	Liquors/water	Medium	Neutralize
Painting	Vapors,overspray/air, water	Medium	--
Heat treatment	unburned gases/air	Low	Vent
Lubricating	Fumes/air	Low	Vent
Assembly	Oils/water	Low	
Load propellants, explosives	Chemicals/water	Low	--

(a) The following raw materials are used in these operations: metals (sheet, plates, extrusions, bar, wire, forgings, castings), steel, aluminum alloys, refractory metals, magnesium alloys, titanium alloys, copper alloys, nickel alloys, ceramics, fiberglass, adhesives, resins, paints, oils, solvents, propellants, and acids/alkali.

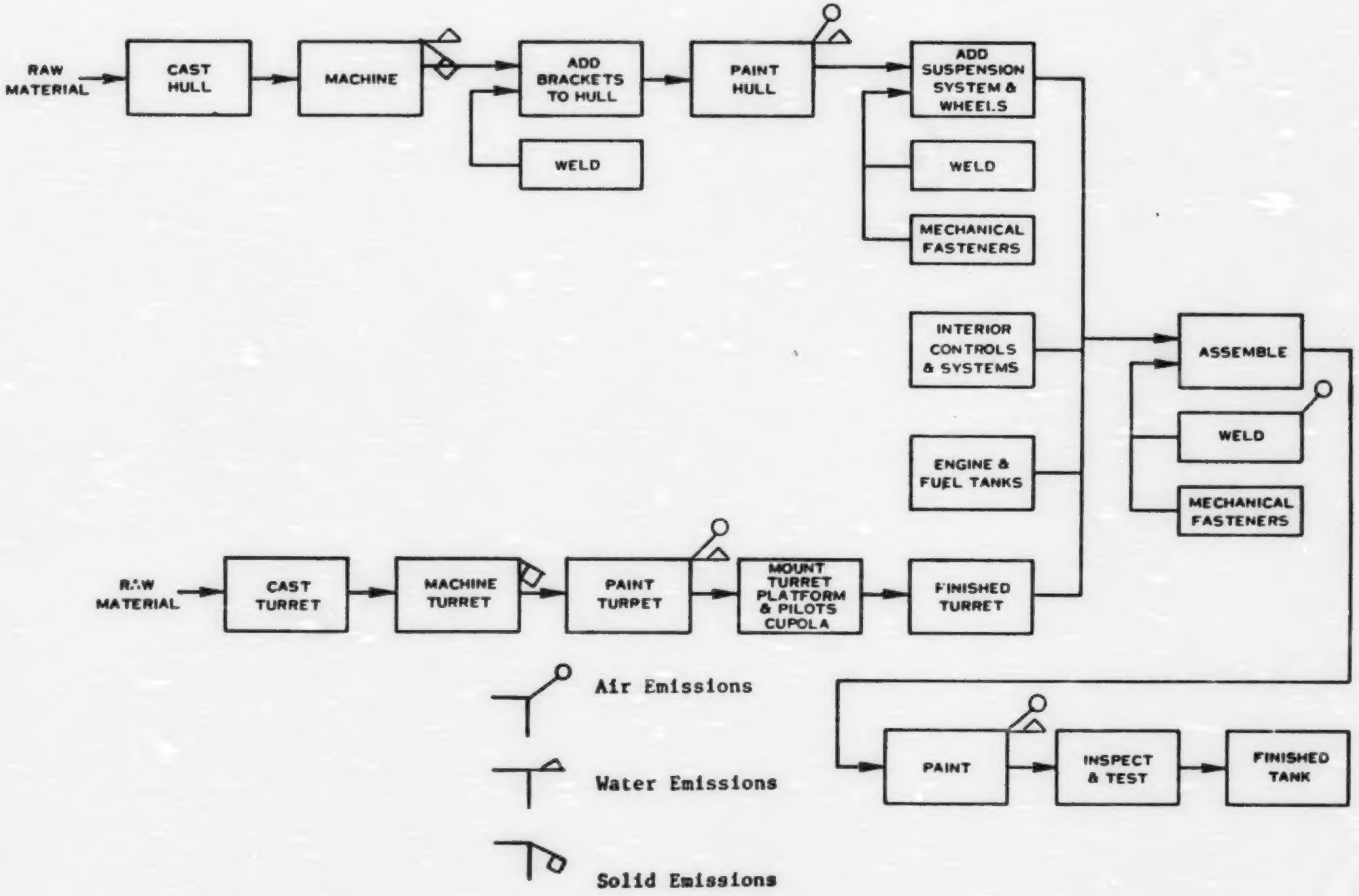

RAW MATERIAL
CAST HULL
MACHINE
ADD BRACKETS TO HULL
WELD
PAINT HULL
ADD SUSPENSION SYSTEM & WHEELS
WELD
MECHANICAL FASTENERS
INTERIOR CONTROLS & SYSTEMS
ENGINE & FUEL TANKS
ASSEMBLE
WELD
MECHANICAL FASTENERS
RAW MATERIAL
CAST TURRET
MACHINE TURRET
PAINT TURRET
MOUNT TURRET PLATFORM & PILOTS CUPOLA
FINISHED TURRET
PAINT
INSPECT & TEST
FINISHED TANK
Air Emissions
Water Emissions
Solid Emissions

FIGURE 105. MANUFACTURE OF MILITARY TANKS.

TABLE 29. MATERIALS AND PROCESSES TYPICAL FOR MISCELLANEOUS TRANSPORTATION EQUIPMENT (TRAVEL TRAILERS, CAMPERS, TANKS, AND OTHER NEC).

Operations (a)	Waste/Media	Potential Levels of Pollution	Current Action
Welding	Fumes/air	Medium/local	masks/vent
Torch cutting	Fumes/air,solid	Low	--
Machining	Chips/solids	Low	--
Riveting	--	--	--
Lubricating	HC/air,water	Medium	--
Sheet forming	Oil/water	Low	--
Stamping	Oil/water	Low	--
Painting	HC/air,water	Low	Venting

(a) The following raw materials are used in these operations: metals (sheet, plate, castings, forgings, metal powder parts, bar, wire),steel, aluminum, iron (castings), solder, plastics, rubber products, oils, glass, paint, batteries, acids/alkali, fiberglass, and resins.

MEASURING, ANALYZING, AND CONTROLLING INSTRUMENTS; PHOTOGRAPHIC, MEDICAL, AND OPTICAL GOODS: WATCHES AND CLOCKS

This industry product group includes establishments engaged in manufacturing instruments (including engineering and scientific) for measuring, testing, analyzing, and controlling, and their associated accessories; optical instruments and lenses; surveying and drafting instruments; surgical, medical and dental instruments, equipment and supplies; ophthalmic goods; photographic equipment and supplies; and watches and clocks.

In 1972 this industry product group consisted of 5,866 establishments which employed 442,600 people, and shipped products valued at $15.3521 billion. Descriptions of manufacturing processes were excerpted from Reference (37).

The segments of the measuring, analyzing, and controlling instruments; photographic, medical, and optical goods; watches and clocks industry included in this analysis consist of the following categories:

- Engineering, laboratory, scientific and research instruments and associated equipment
- Automatic controls for regulating residential and commercial environments and appliances
- Totalizing fluid meters and counting devices
- Instruments for measuring and testing of electricity and electrical signals
- Optical instruments and lens
- Surgical and medical instruments and apparatus
- Ophthalmic goods
- Photographic equipment and supplies
- Watches, clocks, clockwork-operated devices, and parts.

Engineering, Laboratory, Scientific, and Research Instruments and Associated Equipment

This segment includes establishments primarily engaged in manufacturing engineering, laboratory, and scientific instruments, including nautical, navigational, aeronautical, surveying, and drafting equipment, and instruments for laboratory work and scientific research.

Engineering and scientific instruments were produced in 1972 by 721 plants, averaging 51 workers each. Most of these plants (65 percent) employed less than 20 workers. Fifty-two percent of the production was in the area of aeronautical and navigational instruments, while 31 percent was in the laboratory and scientific instrument category. The remaining 17 percent consisted of miscellaneous instruments.

Manufacturing Processes--

Materials used include copper, aluminum, steel, electric motors, vacuum tubes, bearings, and semiconductors. The principal manufacturing operations are mechanical material removal, material forming, assembly operations and material coating.

A wide range of manufacturing processes are used in the scientific instrument industry. This is so mainly because of the differing raw materials and the variety of products produced.

The manufacture of an airborne integrated data system (AIDS) is representative of the scientific instrument industry. As shown in Figure 106, sheet metal stock is stamped, punched, drilled, bent, and formed to make various parts of the chassis. These parts are then assembled by welding and, after assembly, are usually surface treated by anodizing or a similar process. Electrical components are then installed in the completed chassis and wired to complete the AIDS controller itself. To operate, electronic circuit cards must be added to the chassis and interconnections added to outside sensors and systems.

Waste Streams--

Water is used mainly for surface treatment operations and cleaning. Solid waste results from the stamping, drilling and welding operations.

Automatic Controls for Regulating Residential and Commercial Environments and Appliances

This segment includes establishments primarily engaged in manufacturing temperature and related controls for heating and air-conditioning installations and refrigeration applications, which are electrically, electronically, or pneumatically actuated, and which measure and control variables such as temperature and humidity; and automatic regulators used as components of household appliances.

In 1972, environmental controls were produced by 129 plants, averaging 228 workers each. About half of these plants (47 percent) employed more than 20 workers. On a dollar basis, about 50 percent of the environmental controls were temperature-responsive thermostats with the balance being distributed among various other types of environmental controls.

Manufacturing Processes--

Raw materials such as carbon steel, alloy steel, copper, aluminum, and castings are required to produce automatic controls. Several operations are performed on these raw materials, including mechanical material removal,

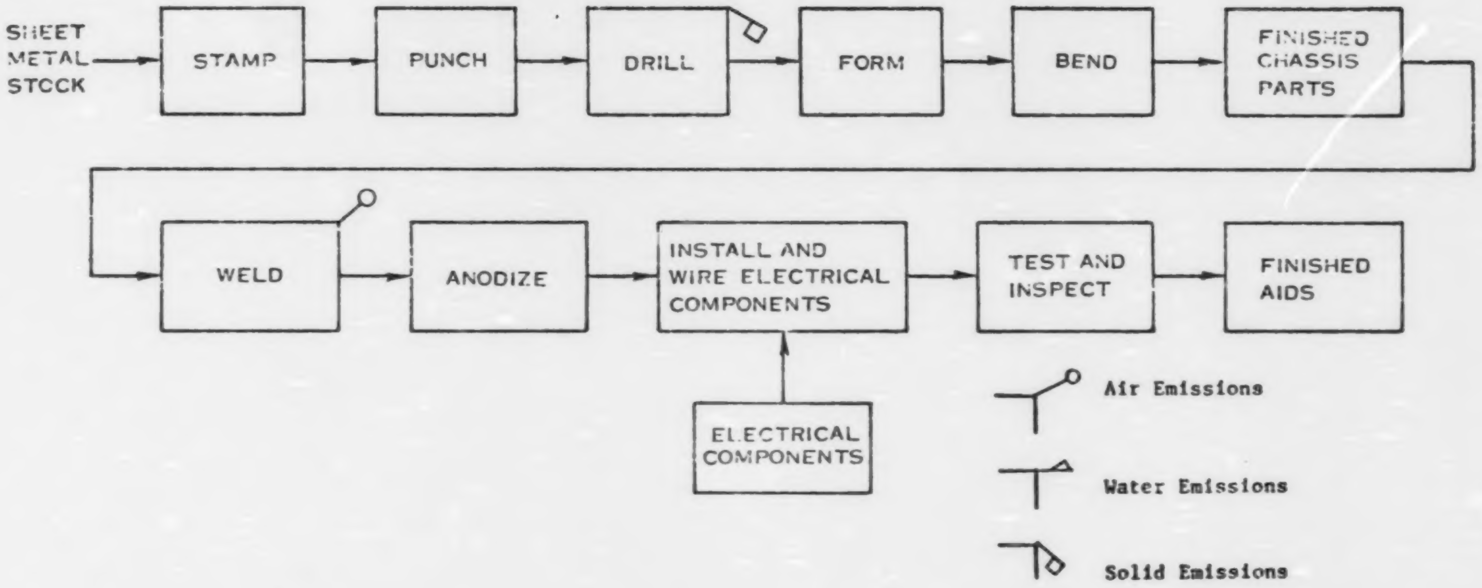

SHEET METAL STOCK
STAMP
PUNCH
DRILL
FORM
BEND
FINISHED CHASSIS PARTS
WELD
ANODIZE
INSTALL AND WIRE ELECTRICAL COMPONENTS
TEST AND INSPECT
FINISHED AIDS
ELECTRICAL COMPONENTS
Air Emissions
Water Emissions
Solid Emissions

FIGURE 106. AIRCRAFT INTEGRATED DATA SYSTEMS (AIDS).

material forming, assembly operations, and material coating.

In general, environmental controls are made by forming mechanical components in linkages to sense the desired environmental parameter and produce a corresponding mechanical output. These are then mounted in a case along with a dial, pointer, and transparent cover.

The manufacture of thermostats is representative of the environmental controls industry. Figure 107 describes this manufacture. Initially, raw mill stock is stamped, shaped, formed, bent, etc., to the configurations required in the final thermostat. The bimetal strip is fabricated by bonding two dissimilar metal strips together. The bimetal strip is then drilled and riveted to a ceramic back plate, and an electrical contact is staked onto the bimetallic strip. Metallic parts (except bimetal strip) are usually finished by plating, anodizing, or applying similar surface treatments. Other components such as the dial cover lens are then assembled to form the final thermostat.

Waste Streams--

Process water is used mainly for plating and cleaning operations and ultrasonic machining. Air emissions result from painting and plating operations and solid waste is generated from stamping, drilling, and grinding operations. Mercury get into the water effluent from the manufacture of mercury switches.

Totalizing Fluid Meters and Counting Devices

This segment includes establishments primarily engaged in manufacturing totalizing (registering) meters for monitoring fluid flows, such as water meters and gas meters. It also includes producers of mechanical and electromechanical counters and associated metering devices.

Fluid meters and counting devices were produced in 1972 by 56 plants, averaging 150 workers each. Most of these plants (73 percent) employed more than 20 workers. Sixty-five percent of the products shipped involved totalizing fluid meters, 14 percent counting devices, and 21 percent nonelectrical motor vehicle instruments.

Manufacturing Processes--

Various stock metals, motors, tubes, and semiconductors are the major identified raw materials. The principal manufacturing operations are mechanical material removal, material forming (metal), assembly operations, and material coating.

In general, fluid meters and counting devices are made by die casting or stamping the indicating wheels and cases which are then surface finished and assembled into the meter.

The manufacture of mechanical counting devices (Figure 108) is representative of the fluid meter and counting devices industry. The shell of

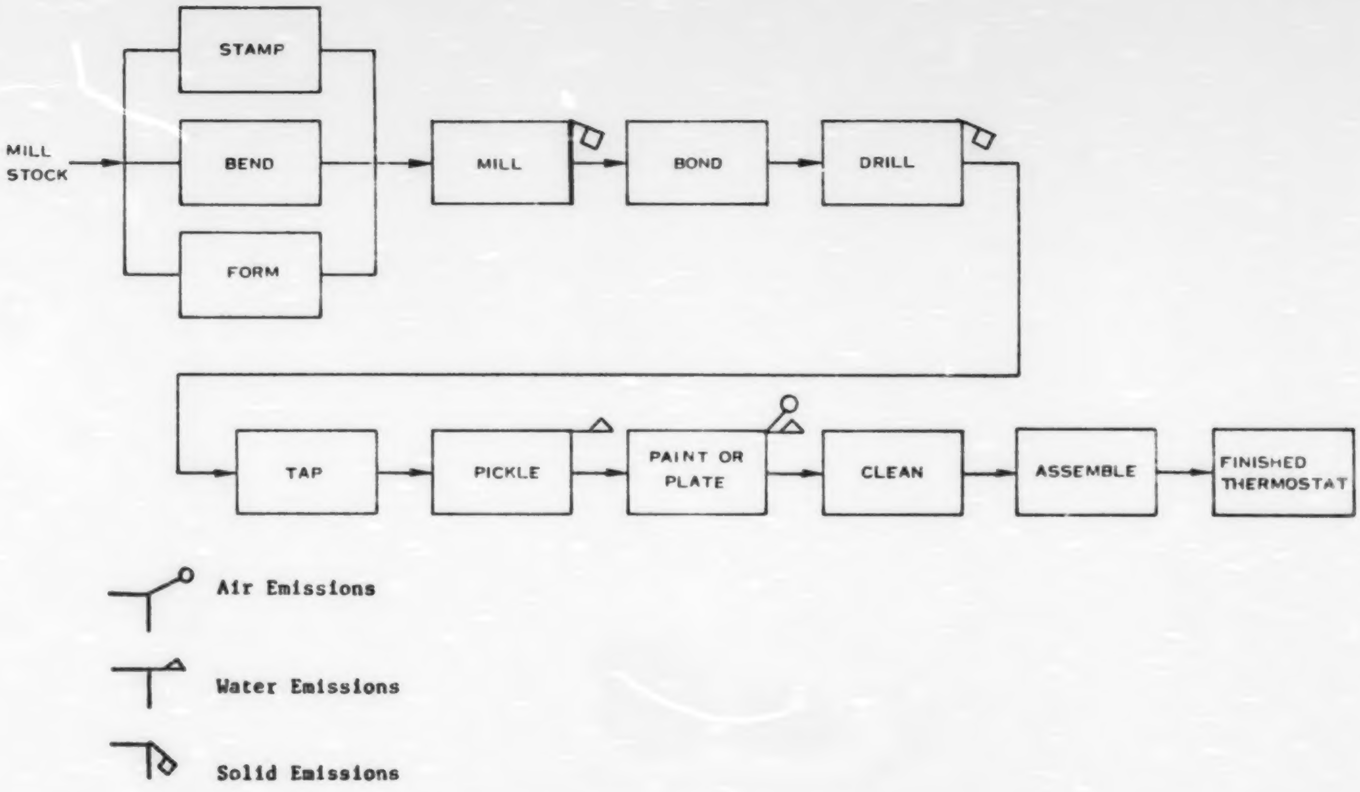

MILL STOCK
STAMP
BEND
FORM
MILL
BOND
DRILL
TAP
PICKLE
PAINT OR PLATE
CLEAN
ASSEMBLE
FINISHED THERMOSTAT
Air Emissions
Water Emissions
Solid Emissions

FIGURE 107. THERMOSTAT MANUFACTURING.

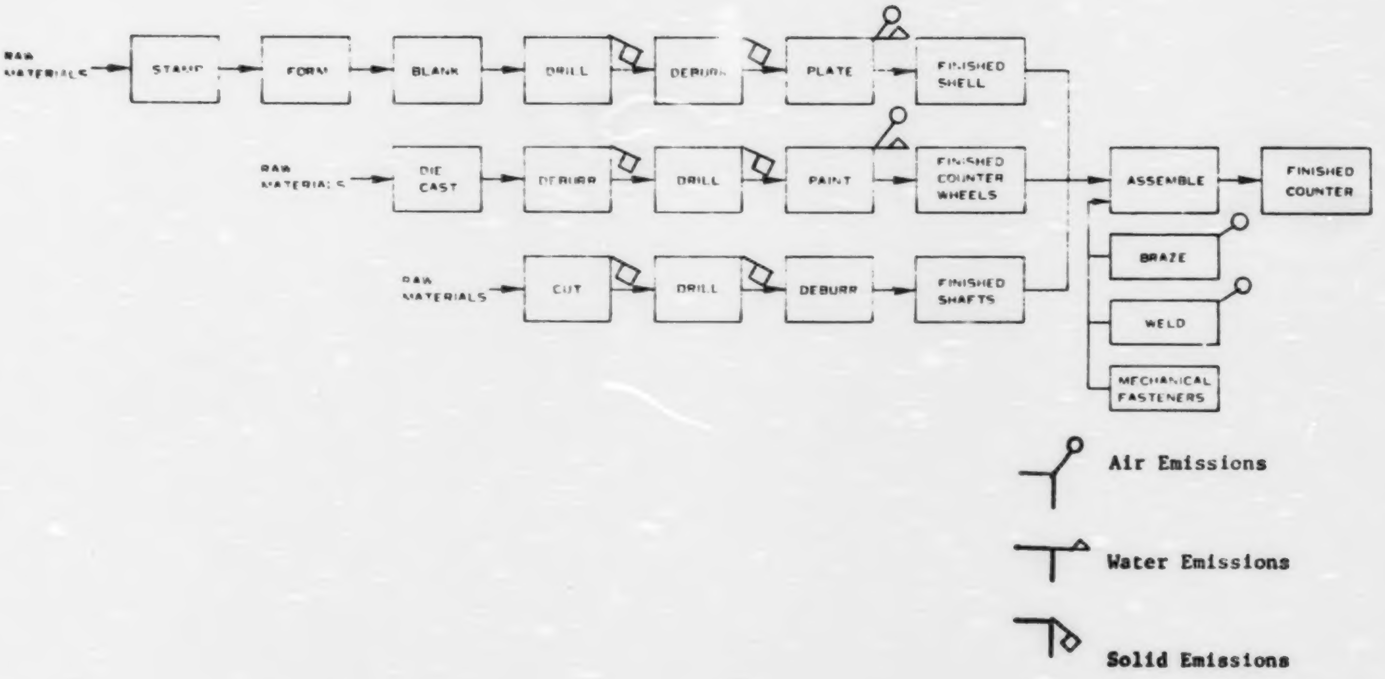

RAW MATERIALS
STAMP
FORM
BLANK
DRILL
DEBURR
PLATE
FINISHED SHELL
RAW MATERIALS
DIE CAST
DEBURR
DRILL
PAINT
FINISHED COUNTER WHEELS
RAW MATERIALS
CUT
DRILL
DEBURR
FINISHED SHAFTS
ASSEMBLE
FINISHED COUNTER
BRAZE
WELD
MECHANICAL FASTENERS
Air Emissions
Water Emissions
Solid Emissions

FIGURE 108. MECHANICAL COUNTING DEVICES MANUFACTURING.

the counter is stamped and formed from heavy-gauge sheet stock with a window blanked into the case for viewing of the counter mechanism. Holes are drilled for mounting bushing blocks, etc. The counter mechanism wheels are die cast, deburred, and drilled. Numbers are painted onto the wheel edge and the wheels placed on a length of steel shaft previously cut to length and drilled. The shaft and wheels are assembled into the case along with a bottom plate (also previously stamped). The case is plated inside and the outside is painted. A molded plastic cover (clear) is installed in the case in front of the counter wheels to seal the case and insure readability.

Waste Streams--

Process water is used mainly for cleaning, plating, and surface-finishing operations. Air emissions result from the painting and plating operations. Solid waste results from deburring and drilling operations.

Instruments for Measuring and Testing of Electricity and Electrical Signals

This segment includes establishments primarily engaged in manufacturing instruments for measuring the characteristics of electricity and electrical signals, such as voltmeters, ammeters, wattmeters, watt-hour meters, demand meters, and equipment for testing the electrical characteristics of electrical, radio, and communication circuits and of internal combustion engines.

Instruments to measure electricity were produced by 622 plants, in 1972, averaging 87 workers each. Most of these plants (60 percent) employed fewer than 20 workers. Sixty-one percent of the production in this category was for test equipment for testing electrical, radio, and communications circuits, while 14 percent was for integrating instruments, and 25 percent for miscellaneous test instruments.

Manufacturing Processes--

Metal mill forms, motors, electron tubes, and semiconductors are the major raw materials. The principal manufacturing operations are material forming, assembling, chemical/electrochemical processing, and material coating.

In general, instruments for measuring electricity are made by forming a chassis and cabinet from metal and/or plastic, and then mounting electronic components and printed circuit boards onto the chassis and wiring these components to the required electric circuit.

The manufacture of an electronic voltmeter is representative of this industry. As shown in Figure 109, sheet metal is stamped, sheared, and bent to form the chassis, the corners of which are then spot welded. The chassis is drilled and punched to accept electrical component mounting. Sheet metal is also stamped, sheared, bent, folded, and welded to form the outer case of the instrument.

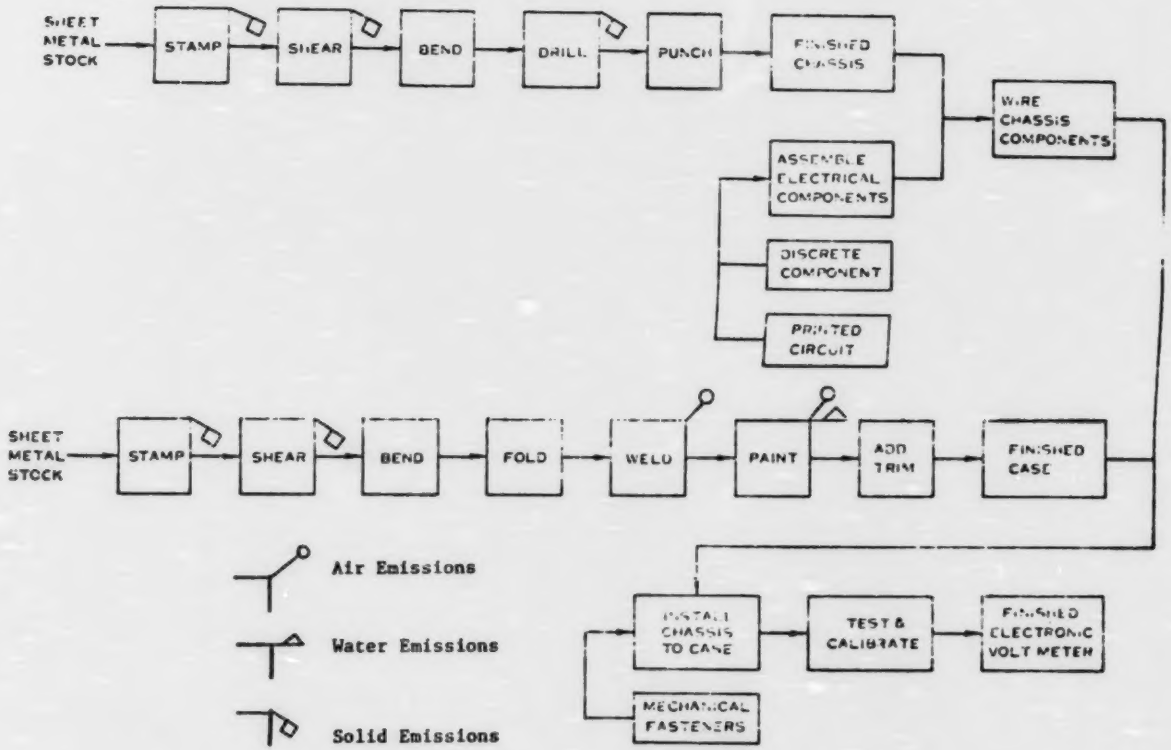

SHEET METAL STOCK
STAMP
SHEAR
BEND
DRILL
PUNCH
FINISHED CHASSIS
WIRE CHASSIS COMPONENTS
ASSEMBLE ELECTRICAL COMPONENTS
DISCRETE COMPONENT
PRINTED CIRCUIT
SHEET METAL STOCK
STAMP
SHEAR
BEND
FOLD
WELD
PAINT
ADD TRIM
FINISHED CASE
INSTALL CHASSIS TO CASE
TEST & CALIBRATE
FINISHED ELECTRONIC VOLT METER
MECHANICAL FASTENERS
Air Emissions
Water Emissions
Solid Emissions

FIGURE 109. ELECTRONIC VOLT METER MANUFACTURING.

Electrical components are next mounted on the chassis, printed circuit boards installed, and interface connectors installed on the front panel and/or rear chassis apron. The electrical components on the chassis are then wired together. After fabrication, the case is painted and trim pieces and handles are installed. The chassis is installed in the cabinet and affixed with hardware, usually by machine or sheet metal screws. The instrument is then tested and calibrated.

Waste Streams--

Process water is used mainly for plating and rinsing operations. Air emissions result from the painting and welding operations.

Optical Instruments and Lenses

This segment includes establishments primarily engaged in manufacturing instruments that measure an optical property; apparatus except photographic that projects or magnifies such as binoculars, prisms, and lenses; optical sighting and fire-control equipment; and related analytical instruments.

Optical instruments and lenses were produced in 1972 by 482 plants, averaging 38 workers each. Most of these plants (72 percent) employed fewer than 20 workers. Seventy-eight percent of the shipment value was for analytical, optical, and scientific instruments and 22 percent for miscellaneous sighting and fire-control systems.

Manufacturing Processes--

Mill shapes of steel and aluminum are the major raw materials. The principal manufacturing operations are mechanical material removal, material forming of the raw materials, and molding and forming nonmetals.

In general, optical instruments are made by fabricating a housing or other supporting structure to hold the optical elements which are ground and polished prior to installation in the housing.

The manufacture of binoculars (Figure 110) is representative of the optical instruments and lens industry. Standard commercial prismatic binoculars are generally manufactured with molded plastic cases and glass lenses. The various portions of the case are slush molded. The individual pieces are then deburred and lens and prism mounting areas are machined for a precise fit. The lenses and prisms are then ground, polished, and mounted in the case. After installation and adjustment of the lens, the lens retainers are installed and final adjustments are made in the optic system. Lens covers are installed to complete the binoculars.

Waste Streams--

Process water is used primarily for plating and painting, and as a suspension medium for grinding and polishing compounds in making lenses.

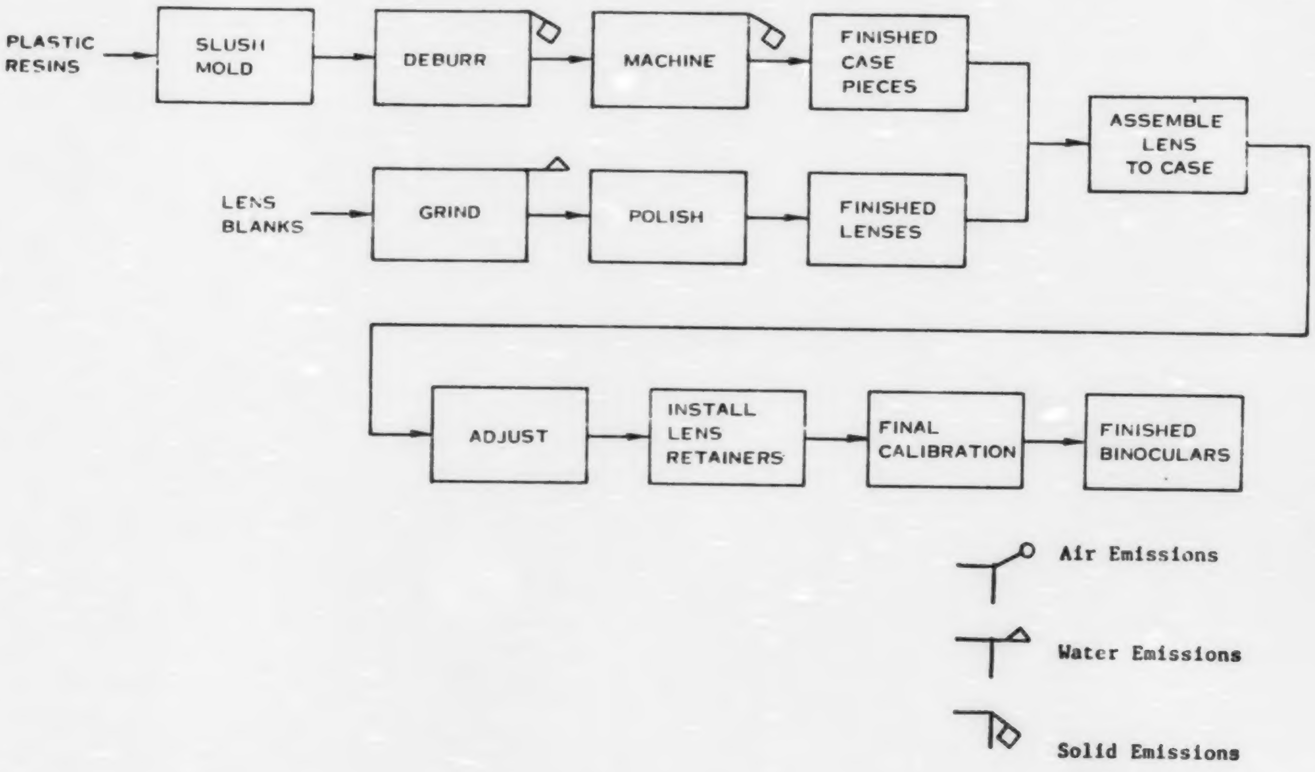

PLASTIC RESINS
SLUSH MOLD
DEBURR
MACHINE
FINISHED CASE PIECES
LENS BLANKS
GRIND
POLISH
FINISHED LENSES
ASSEMBLE LENS TO CASE
ADJUST
INSTALL LENS RETAINERS
FINAL CALIBRATION
FINISHED BINOCULARS
Air Emissions
Water Emissions
Solid Emissions

FIGURE 110. BINOCULARS.

Surgical and Medical Instruments and Apparatus

This segment includes establishments primarily engaged in manufacturing medical, surgical, ophthalmic, and veterinary instruments and apparatus.

Surgical and medical instruments were produced in 1972 by 487 plants, averaging 66 workers each. Most of the plants (61 percent) employed fewer than 20 workers. Surgical instruments and hypodermic syringes constituted 40 percent of the production and hospital furniture about 11 percent.

Manufacturing Processes--

Raw materials include metal mill forms, plastics, and fabrics. The principal manufacturing operations are mechanical material removal, molding and forming, and material coating.

In general, surgical and medical instruments are made by metal-working operations, such as turning, drawing, and grinding to form and finish the raw stock into the desired surgical instrument. Process water is used mainly for plating, cleaning, and sterilization of the products.

Because of the diversity of products and materials used in the surgical and medical instruments industry, no single product can be considered typical. However, the manufacture of medical scissors (Figure 111) and operating tables (Figure 112) illustrate many of the manufacturing processes used in this industry. Scissors for medical purposes are stamped from stainless steel sheet stock. The mating halves are then ground, buffed, and formed. One half section is drilled and tapped, while the other is clearance drilled for a mounting screw. The halves are assembled using a machine screw and the scissors are then cleaned.

Operating room furniture, such as an operating table, is made of heavy gauge metal for stability. The base is cast and machined at the mounting surfaces and at the junction of the base and bed sections. The upper bed portion is die cast, machined at the mounting interface, and buffed. Cross braces are welded to the base and a sheet plate is welded to the braces as a platform for the mattress. Holes are drilled and tapped for control levers, if required, to rotate or otherwise change the position of the bed. The bed assembly is completed by plating, and cleaning.

Waste Streams--

Process water is used in the cleaning and plating operations. Air emissions result from the grinding, buffing, welding, and brazing operations.

Ophthalmic Goods

This segment includes establishments primarily engaged in manufacturing ophthalmic frames, lenses, and sunglass lenses.

In 1972 this industry was composed of 499 establishments, averaging 54

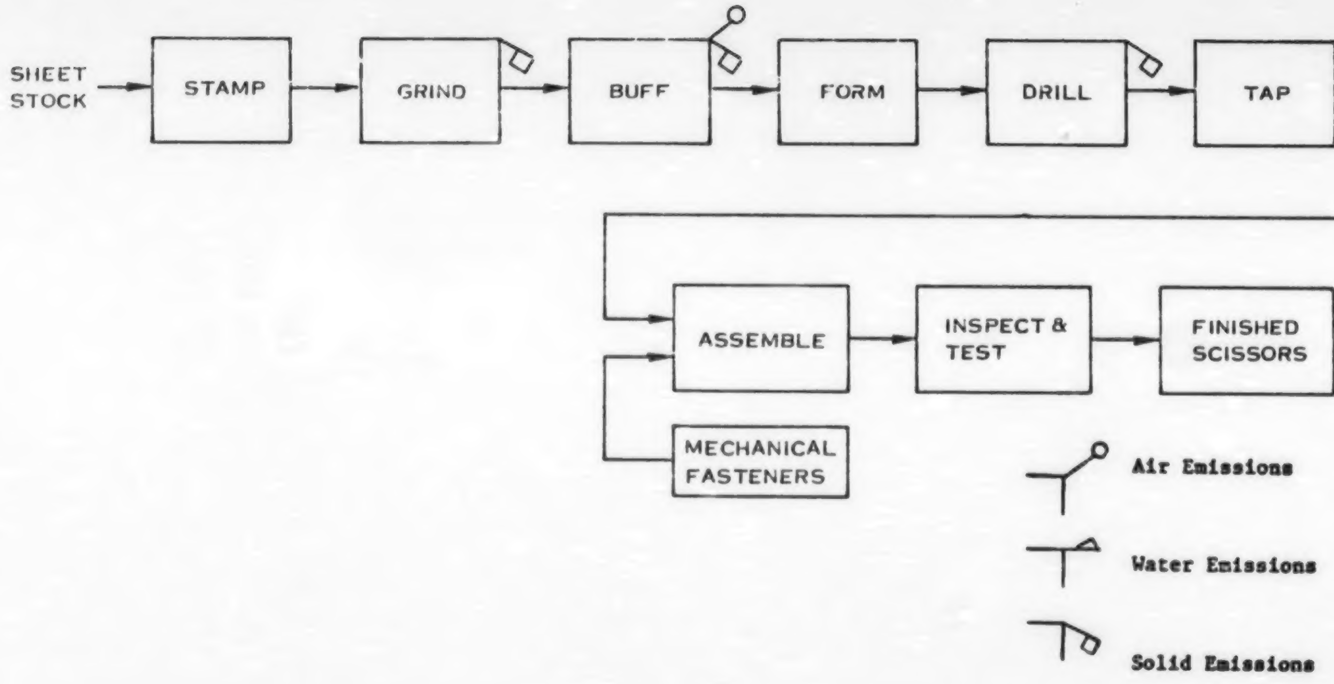

SHEET STOCK
STAMP
GRIND
BUFF
FORM
DRILL
TAP
ASSEMBLE
MECHANICAL FASTENERS
INSPECT & TEST
FINISHED SCISSORS
Air Emissions
Water Emissions
Solid Emissions

FIGURE 111. MEDICAL SCISSORS MANUFACTURING.

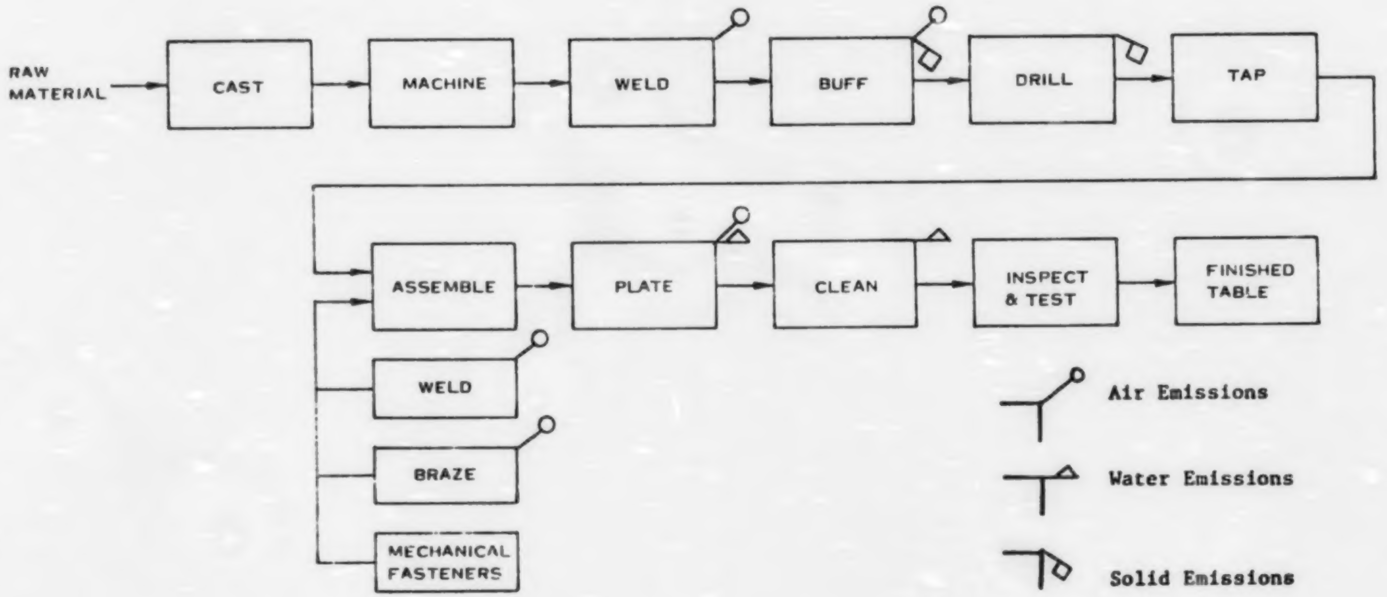

RAW MATERIAL
CAST
MACHINE
WELD
BUFF
DRILL
TAP
ASSEMBLE
PLATE
CLEAN
INSPECT & TEST
FINISHED TABLE
WELD
BRAZE
MECHANICAL FASTENERS
Air Emissions
Water Emissions
Solid Emissions

FIGURE 112. OPERATING TABLE MANUFACTURING.

employees each. They shipped primary products valued at $465 million.

Manufacturing Processes--

Glass blanks for lenses and metal and/or plastic for frames are the major raw materials. The principal manufacturing operations are mechanical material removal in forming the glass lenses and material forming with subsequent chemical processing in making metal frames. Plastic frames are made by injection-molding techniques.

The manufacture of eyeglass lenses and frames is representative of the ophthalmic goods industry. A typical operation for making eyeglass lenses and frames is shown in Figure 113. The glass blanks are first ground using an emery slurry, then rinsed. Next a polishing operation is performed using a metallic oxide compound. This is followed by a second rinse. The blank is then edged on a grinding wheel to obtain a smooth, even edge on the lens.

Plastic eyeglass frames are generally made by injection molding of plastic formulations. The molded members are polished and then assembled with hinge hardware, etc.

Metal frames are fabricated from sheet stock by stamping and bending operations. The formed sections are then assembled by spot welding and riveting. Following assembly, the metal is electro-finished by any of several technqiues such as plating or anodizing.

Waste Streams--

Process water is used mainly as a suspension medium for grinding and polishing compounds in the lens manufacture. It is also used for plating rinses in the manufacture of metal rims.

Photographic Equipment and Supplies

This segment includes establishments primarily engaged in manufacturing (1) photographic apparatus, equipment, parts, attachments, and accessories, such as still and motion-picture cameras and projection apparatus; photocopy and microfilm equipment; blueprinting and diazotype (white printing) apparatus and equipment; and other photographic equipment and (2) sensitized film, paper, cloth, and plates, and prepared photographic chemicals for use therewith.

Photographic equipment and supplies were produced in 1972 by 616 plants, averaging 152 workers each. Most of these plants (63 percent) employed fewer than 20 workers. About 50 percent of the production was in the area of cameras and equipment, and 50 percent in the photosensitized material category.

Manufacturing Processes--

A wide range of raw materials are used in this industry. The principal manufacturing operations are chemical processing in manufacturing of film,

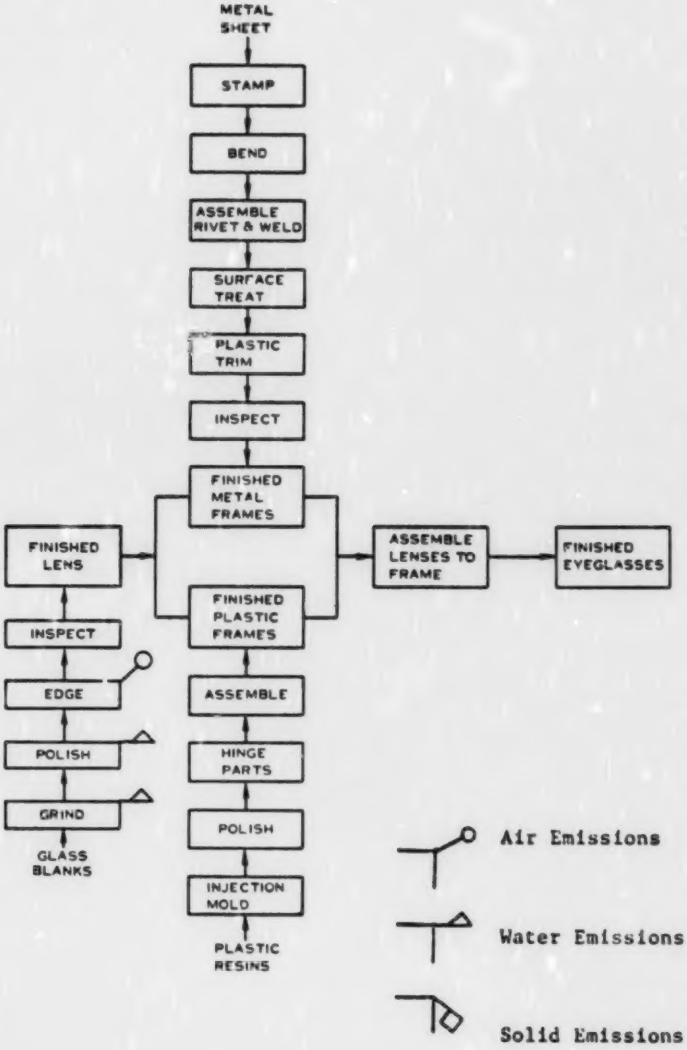

METAL SHEET
STAMP
BEND
ASSEMBLE RIVET & WELD
SURFACE TREAT
PLASTIC TRIM
INSPECT
FINISHED METAL FRAMES
FINISHED LENS
ASSEMBLE LENSES TO FRAME
FINISHED EYEGLASSES
FINISHED PLASTIC FRAMES
INSPECT
EDGE
ASSEMBLE
POLISH
HINGE PARTS
GRIND
POLISH
GLASS BLANKS
INJECTION MOLD
PLASTIC RESINS
Air Emissions
Water Emissions
Solid Emissions

FIGURE 113. EYEGLASS MANUFACTURING.

plastic molding and assembly in the making of cameras, and mechanical material removal and material forming (metals) in the manufacture of photographic equipment, such as projectors, and cameras.

Because of the diversity of products and materials used in the photographic industry, no single product can be considered typical. However, the manufacture of negative film and cameras are good examples of the types of manufacturing processes used in this product area. These manufacturing processes are illustrated in Figures 114 and 115. As shown in Figure 144, film is made by preparing an emulsion of silver salts, gelatine, and other special-purpose chemicals which are then spread in a thin uniform layer on a clear acetate or other plastic base. The negative film is then dried and packaged in a variety of configurations, e.g., sheet, cartridge, and roll.

The manufacturing of a camera is a good example of the manufacture of photographic apparatus (Figure 115). In the case of a pocket-type camera (chosen because of the high volume of sales) plastic parts such as the case, lens, and lens cover are injection molded. Metal parts, for the shutter, battery contacts, etc., are stamped and formed to the desired configurations. The parts are then assembled to form the completed camera.

Waste Streams--

Process water is used mainly for the processing of film emulsions and other photosensitized materials, and for plating and cleaning in the making of cameras. Solid waste results from the deburring operations, grinding and polishing of the lens.

Watches, Clocks, Clockwork Operated Devices, and Parts

This segment includes establishments primarily engaged in manufacturing clocks (including electric), watches, watchcases, mechanisms for clockwork-operated devices, and clock and watch parts. This industry includes establishments primarily engaged in assembling clocks and watches from purchased movements and cases. Principal products are:

- Appliance timers
- Chronographs, spring wound
- Chronometers, spring wound
- Clock materials and parts, except crystals and jewels
- Clocks, including electric
- Mechanisms for clockwork-operated devices
- Movements, watch or clock
- Timers for industrial use, clockwork mechanism only

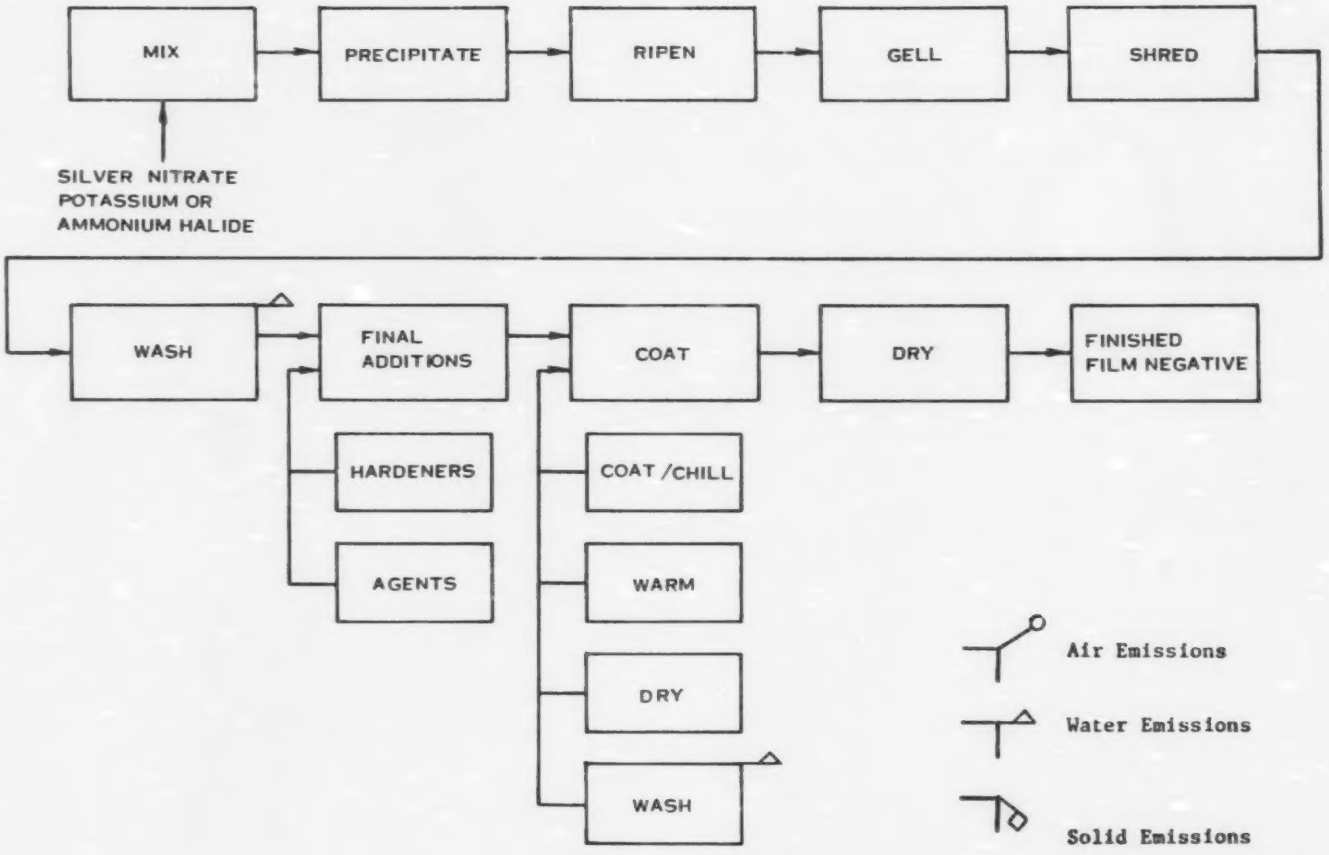

MIX
PRECIPITATE
RIPEN
GELL
SHRED
SILVER NITRATE
POTASSIUM OR
AMMONIUM HALIDE
WASH
FINAL
ADDITIONS
COAT
DRY
FINISHED
FILM NEGATIVE
HARDENERS
AGENTS
COAT /CHILL
WARM
DRY
WASH
Air Emissions
Water Emissions
Solid Emissions

FIGURE 114. FILM NEGATIVE MANUFACTURING.

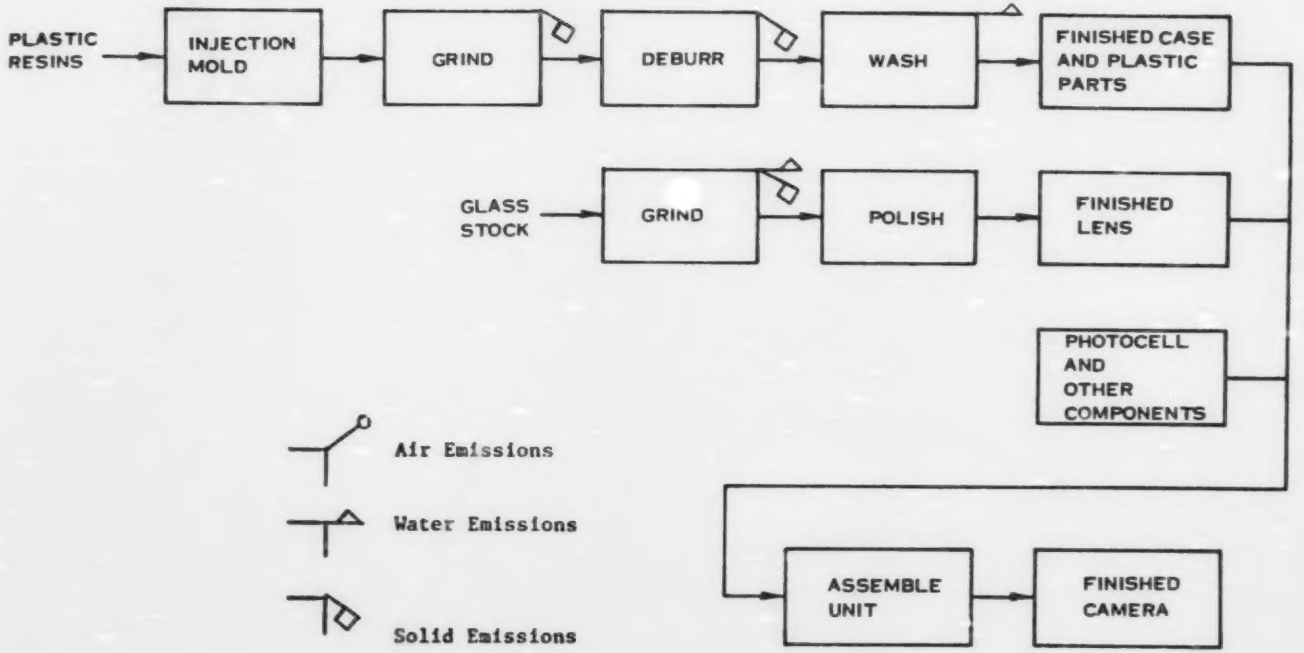

PLASTIC RESINS
INJECTION MOLD
GRIND
DEBURR
WASH
FINISHED CASE AND PLASTIC PARTS
GLASS STOCK
GRIND
POLISH
FINISHED LENS
PHOTOCELL AND OTHER COMPONENTS
ASSEMBLE UNIT
FINISHED CAMERA
Air Emissions
Water Emissions
Solid Emissions

FIGURE 115. CAMERA MANUFACTURING.

- Watchcases

- Watches and parts: except crystals and jewels.

Watches, clocks, and watchcases were produced in 1972 by 202 plants, averaging 157 workers each. About half of these plants (49 percent) employed more than 20 workers. The largest product group was clocks, with a production of over 24 million, followed by watches (with imported movements) with over 9 million units.

Manufacturing Processes--

Timing motors, watchcases, and watch movements are the major raw materials. The principal manufacturing operations are mechanical material removal and material forming on watch and clock parts, plastic molding operations, electrochemical processing, and assembly operations.

In general, clocks and watches are made by assembly of precision mechanical parts into a metal or plastic case that is then equipped with a face and clear cover.

The manufacture of clocks is representative of the watch and clock industry. Figure 116 describes the manufacturing operation for clocks. The plastic case and accessory plastic parts are generally injection molded. The various timing gears for the clock movement are produced by stamping (for the larger gears) and by extrusion and cutting (for the small, thick gears). Grinding, deburring, and cleaning of the gears precedes assembly. The frame members for the movement are formed by stamping, blanking and bending operations. Holes are drilled and tapped, and bushings installed where required. The movement is then assembled, and a timing motor (manufactured in-house or purchased) is installed. The movement is then inserted in the case along with the face and fastened to the case. Hands, which may be stamped or formed, are fastened to the movement. A clear plastic lens and bezel assembly is installed, completing the clock. The clock is inspected and packaged for shipment.

Waste Streams--

Process water is used mainly for plating, machining, and cleaning operations. Air emissions result from the plating and welding operations. Solid waste results from grinding and drilling operations.

MISCELLANEOUS MANUFACTURING INDUSTRY

This product industry includes establishments primarily engaged in manufacturing products not classified in any other manufacturing product group. Industries in this group fall into the following categories: jewelry, silverware and plated ware; musical instruments; toys, sporting and athletic goods; pens, pencils, and other office and artists' materials; buttons, costume novelties, miscellaneous notions; brooms and brushes; caskets; and other miscellaneous manufacturing industries.

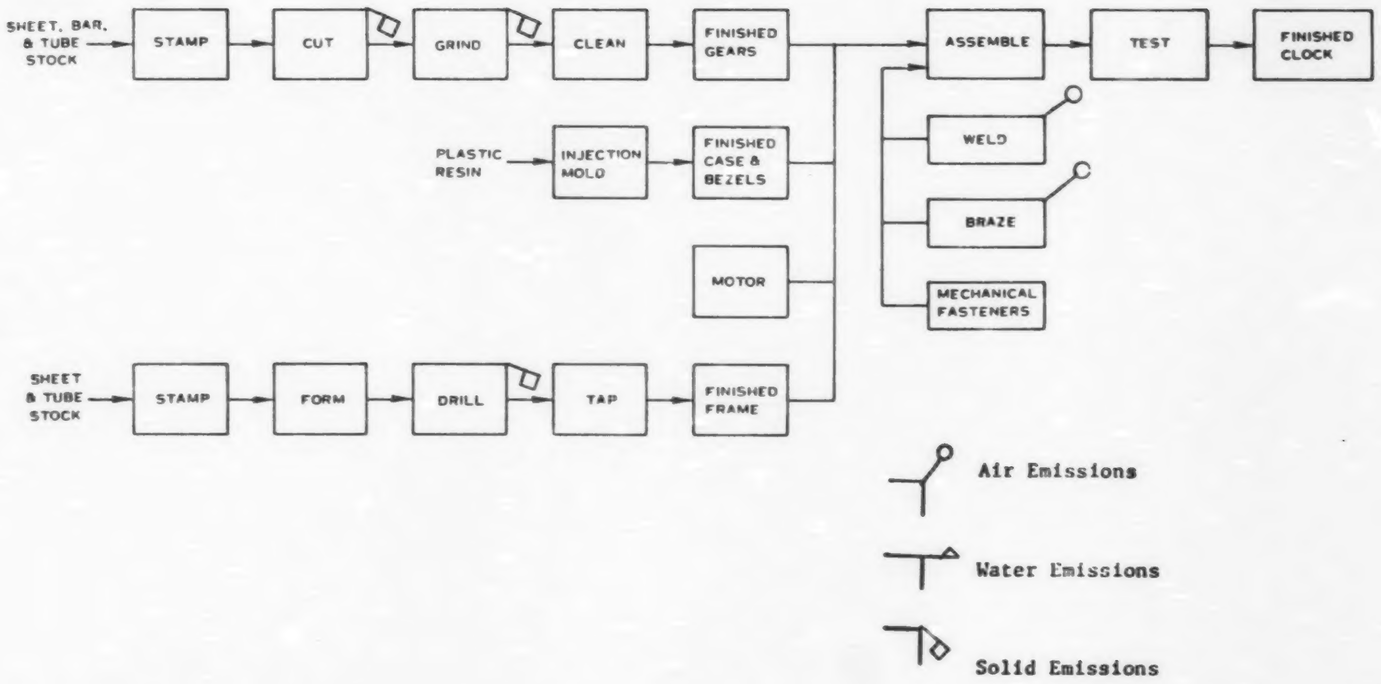

SHEET, BAR, & TUBE STOCK
STAMP
CUT
GRIND
CLEAN
FINISHED GEARS
PLASTIC RESIN
INJECTION MOLD
FINISHED CASE & BEZELS
MOTOR
SHEET & TUBE STOCK
STAMP
FORM
DRILL
TAP
FINISHED FRAME
ASSEMBLE
WELD
BRAZE
MECHANICAL FASTENERS
TEST
FINISHED CLOCK
Air Emissions
Water Emissions
Solid Emissions

FIGURE 116. CLOCK MANUFACTURING.

This product group consisted of 15,012 establishments, employed 443,800 persons and shipped products valued at $12.041 billion in 1972. Descriptions of the manufacturing processes and flow diagrams were excerpted from Reference 37. The segments of miscellaneous manufacturing industry included in this analysis consist of the following:

- Jewelry, precious metal
- Silverware, plated ware, and stainless steel ware
- Musical instruments
- Games, toys, and children vehicles; except dolls and bicycles
- Dolls
- Pens, mechanical pencils, and parts
- Sporting and athletic goods
- Burial caskets.

Jewelry, Precious Metals

This segment includes establishments primarily engaged in manufacturing jewelry and other articles worn on or carried about the person, made of precious metals with or without stones (including the setting of stones where used), including cigarette cases and lighters, vanity cases and compacts, trimmings for umbrellas and canes and jewel settings and mountings.

Precious metal jewelry was produced by 1524 plants, and shipments of primary products were valued at $947 million in 1972. Most of these plants (80 percent) employed fewer than 20 workers.

Manufacturing Processes--

Gold, silver, platinum and solder preforms are the major raw materials used to produce rings, necklaces, broaches, and other jewelry items.

The principal manufacturing operations are material forming, physical property modification, mechanical material removal, and assembly operations. In addition, casting is used to obtain intricate patterns in large items such as class rings.

In general, jewelry is made by forming the basic raw materials into the desired configurations by casting or other means. Then a surface treatment such as a precious metal plating is applied.

The manufacture of a gold class ring (Figure 117) is representative of the precious metal jewelry industry. A gold alloy is melted and poured into a mold to form the crown of the ring. Once the gold has set, the crown is removed from the mold, deburred and polished. The surface is then

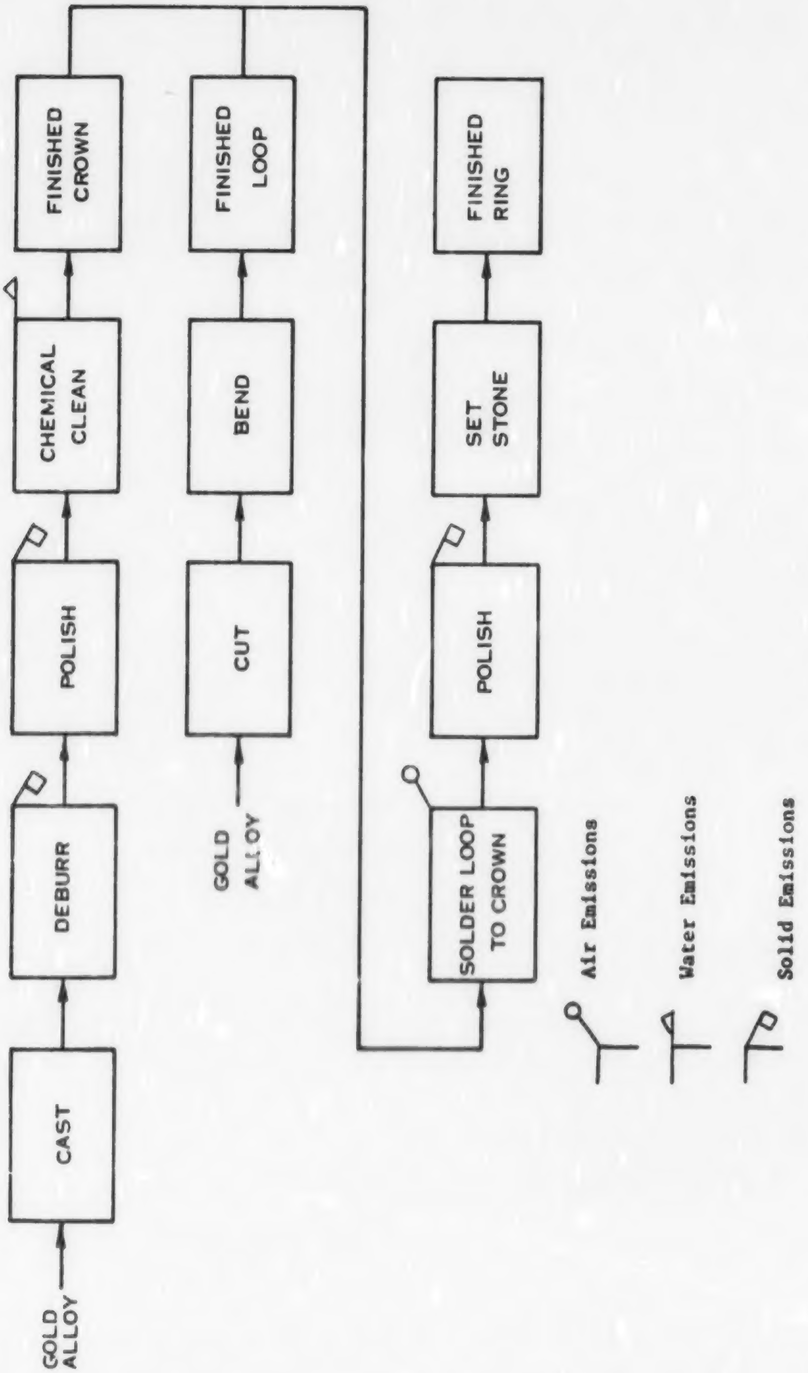

GOLD ALLOY
CAST
DEBURR
POLISH
CHEMICAL CLEAN
FINISHED CROWN
GOLD ALLOY
CUT
BEND
FINISHED LOOP
SOLDER LOOP TO CROWN
POLISH
SET STONE
FINISHED RING
Air Emissions
Water Emissions
Solid Emissions

FIGURE 117. CLASS RING MANUFACTURING.

chemically cleaned using a sulfuric acid pickling solution to remove the black compound formed on the ring's surface during casting. A loop is formed around an arbor and is gold soldered to the crown. A stone is then set into the crown.

Waste Streams--

Process water is used mainly for cleaning prior to and after surface treatments.

Silverware, Plated Ware, and Stainless Steelware

This segment includes establishments primarily engaged in manufacturing flatware (including knives, forks, and spoons), hollow ware, toilet ware, ecclesiastical ware, and related products made of sterling silver; of metal plated with silver, gold, or other metal; of nickel silver, of pewter; or of stainless steel. Silverware and plated ware were produced by 205 plants, and primary products shipped were valued at $308 million in 1972. Most of these plants (65 percent) employed fewer than 20 workers.

Manufacturing Processes--

The major raw materials used in this industry are steel, copper and precious metals. The principal manufacturing operations are mechanical material removal, material forming, and electrochemical processing.

In general, silverware is made by forming the base metal to the desired shape by stamping and forming sheet steel and then finishing the metal surface by plating.

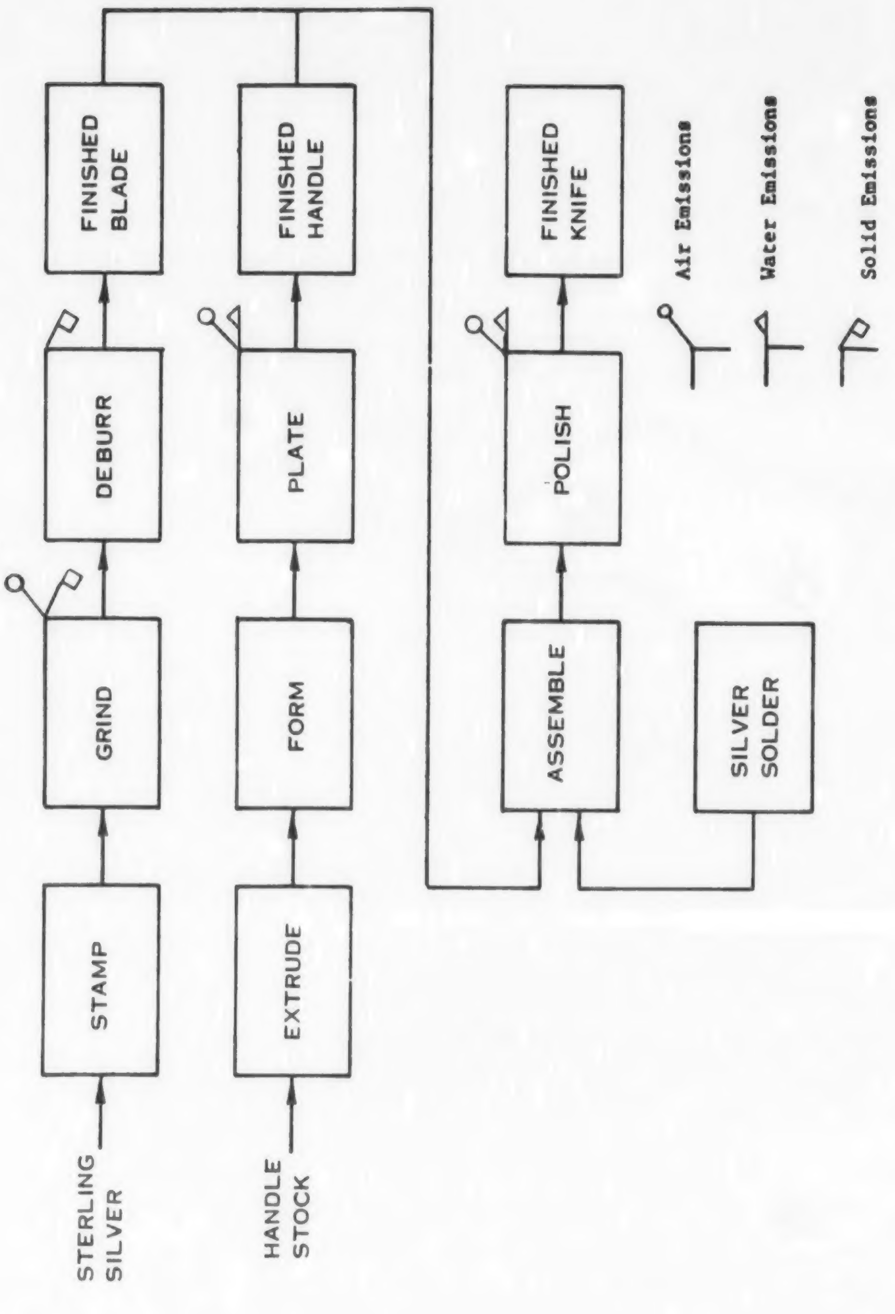
The manufacture of sterling silver plated knives (Figure 118) is representative of the silverware industry. The blade is first stamped from a stainless steel sheet to the desired configuration. It is then ground to produce a cutting edge and deburred, if necessary. The handle is extruded from a silver alloy, such as nickel silver, to form a hollow shell. One end is closed, while the other has a slit for the blade. The handle is polished and then silver plated and the blade is inserted and silver soldered. Finally, the whole knife is polished.

Waste Streams--

Process water is used mainly for plating and cleaning. Air emissions result from polishing and grinding operations. Solid waste results from the grinding and polishing operations.

Musical Instruments

This segment includes establishments primarily engaged in manufacturing pianos, with or without player attachments; organs; other musical instruments; and parts and accessories for musical instruments.



STERLING SILVER
STAMP
GRIND
DEBURR
FINISHED BLADE
HANDLE STOCK
EXTRUDE
FORM
PLATE
FINISHED HANDLE
ASSEMBLE
SILVER SOLDER
POLISH
FINISHED KNIFE
Air Emissions
Water Emissions
Solid Emissions

FIGURE 118. STERLING SILVER PLATED KNIFE MANUFACTURING.

Musical instruments were produced by 344 plants, and shipped primary products were valued at $521 million in 1972. Most of these plants (68 percent) employed fewer than 20 workers.

Manufacturing Processes--

A large variety of raw materials are involved in this industry, ranging from wood to precious metals. The principal manufacturing operations are as varied as the musical instruments produced. For instance, pianos are primarily manufactured by woodworking, whereas horns are fabricated by material forming of brass tubing.

Because of the diversity of products and materials used in the musical instrument industry, no single product can be considered typical of the manufacturing operations performed. However, the manufacture of pianos and trumpets are good examples. As shown in the process flow diagram of Figure 119, pianos are constructed primarily of wood, with a cast iron string frame and steel strings. The string frame, after being cast, is machined as required for mounting to the sounding board, and for proper insertion of the string tension adjustment pins. The remainder of the construction is primarily woodworking--cutting, planing, glueing, bolting, etc.

The manufacturing of a trumpet, shown in Figure 120, is representative of the manufacturing of brasswind instruments in general. The operation starts with a tube of the base material, usually brass, which is bent in sections to form the various pieces of the instrument. The valve housings, also made of tubing, are machined to a precision inside dimension and drilled in appropriate locations for mounting to the interconnecting tubing. The various tubing sections are then brazed to the valves. Another section of tubing is then drawn and flared to form the bell of the trumpet, and it is brazed to the pipe section on the horn. The entire instrument is then plated and polished prior to insertion of the valve mechanisms, which are machined and finished in a separate operation.

Waste Streams--

Process water is used mainly for plating operations, rinsing, and lubricant in some metalworking operations. Solid waste is generated by the various woodworking operations. Air emissions result from the coating and plating operations.

Games, Toys, and Children's Vehicles; Except Dolls and Bicycles

This segment includes establishments primarily engaged in manufacturing games and game sets for adults and children, and mechanical and nonmechanical toys.

Games, toys and childrens vehicles were produced by 665 plants, and primary products shipped were valued at $1,739 billion in 1972. Most of these plants (58 percent) employed fewer than 20 workers.

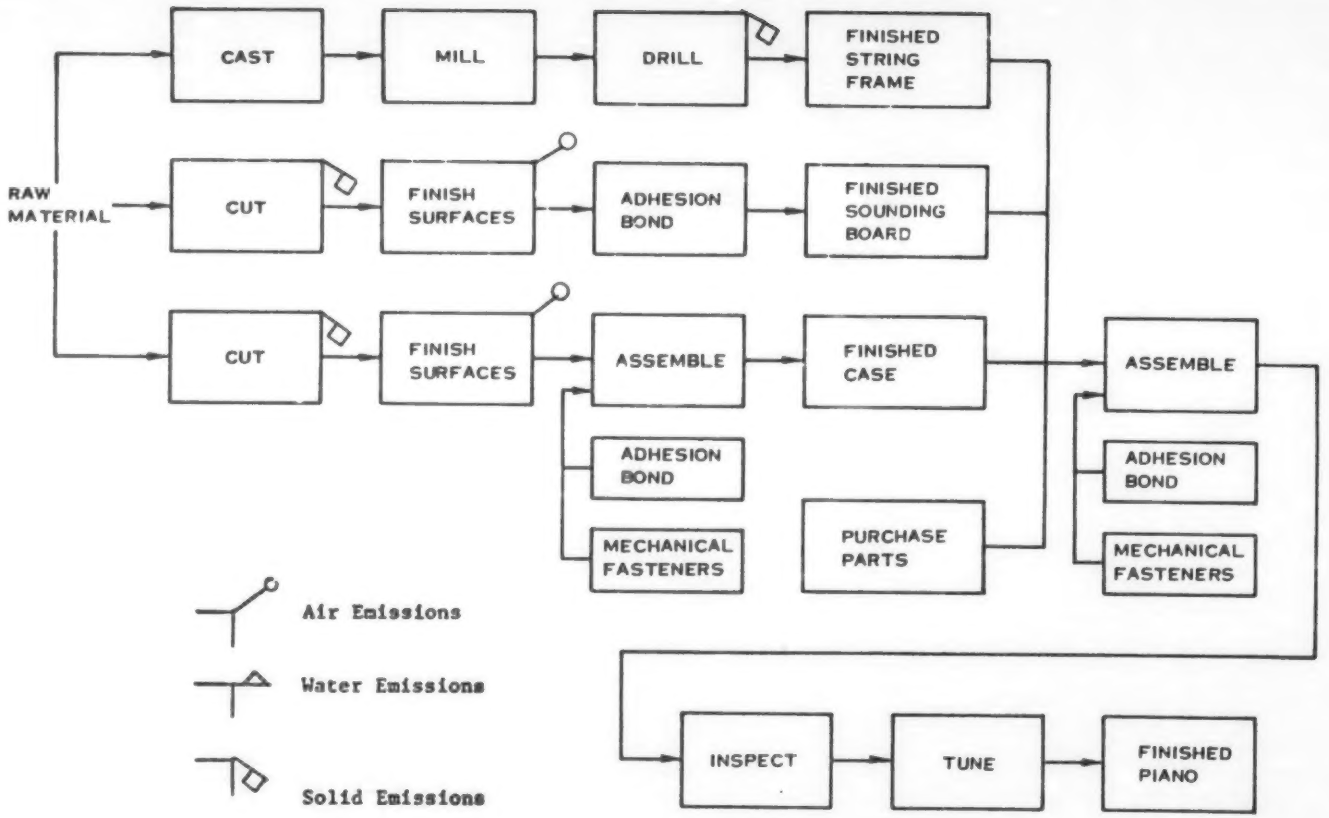

RAW MATERIAL
CAST
MILL
DRILL
FINISHED STRING FRAME
CUT
FINISH SURFACES
ADHESION BOND
FINISHED SOUNDING BOARD
CUT
FINISH SURFACES
ASSEMBLE
ADHESION BOND
MECHANICAL FASTENERS
FINISHED CASE
PURCHASE PARTS
ASSEMBLE
ADHESION BOND
MECHANICAL FASTENERS
INSPECT
TUNE
FINISHED PIANO
Air Emissions
Water Emissions
Solid Emissions

FIGURE 119. PIN PIANO MANUFACTURING.

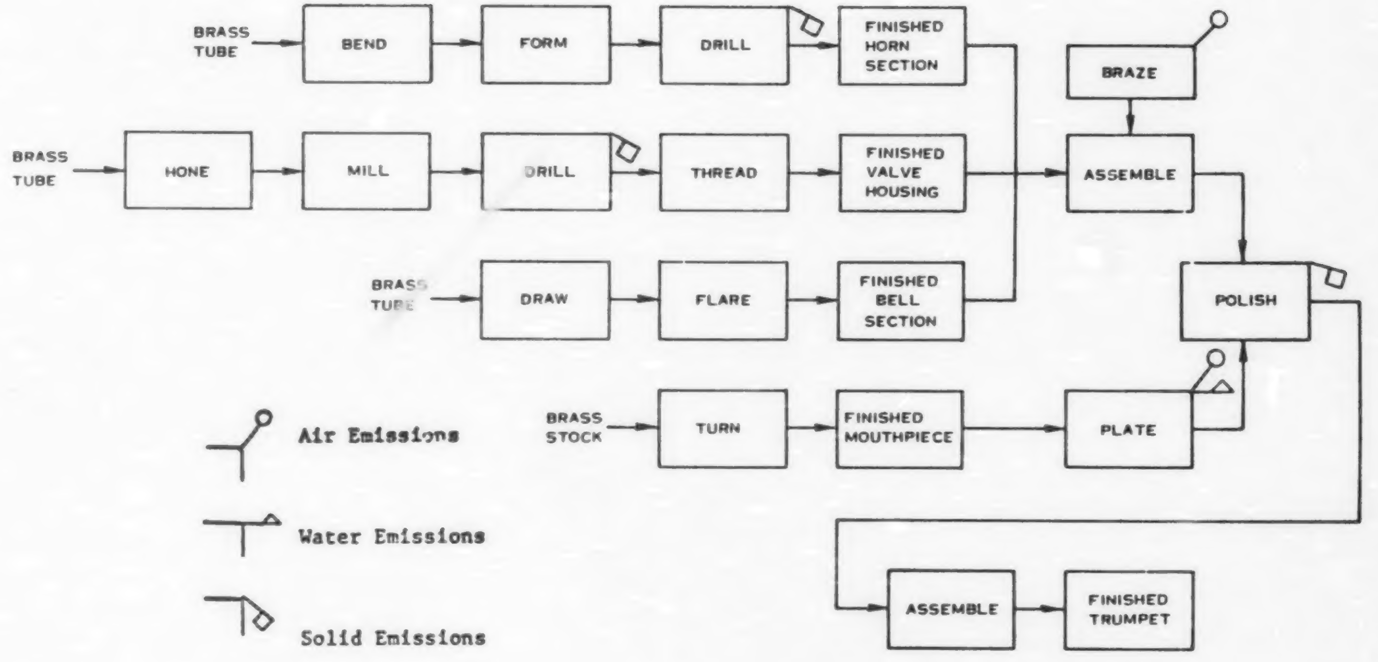

BRASS TUBE
BEND
FORM
DRILL
FINISHED HORN SECTION
BRASS TUBE
HONE
MILL
DRILL
THREAD
FINISHED VALVE HOUSING
BRASS TUBE
DRAW
FLARE
FINISHED BELL SECTION
BRAZE
ASSEMBLE
POLISH
BRASS STOCK
TURN
FINISHED MOUTHPIECE
PLATE
ASSEMBLE
FINISHED TRUMPET
Air Emissions
Water Emissions
Solid Emissions

FIGURE 120. TRUMPET MANUFACTURING.

Manufacturing Processes--

Metal mill shapes, plastics, fabrics, and paperboard containers are the major raw materials. The principal manufacturing operations are mechanical material removal, material forming, plastic molding, and material coating.

A wide range of diverse manufacturing processes are used in the games, toys, and children's vehicles industry. This is due to the differing raw materials and to the diversity of finished products in this industry.

Because of the diversity of products and materials used in the games, toys, and children's vehicles industry, no single product can be considered typical. However, the manufacture of wagons is a good example of the manufacturing operations performed in this industry. As shown in Figure 121, the body of the wagon is stamped from a piece of sheet metal stock, then bent and formed to make the sides and lip of the body. The body is drilled to accept mounting hardware, then cleaned and painted. Brackets for the wheels are stamped, bent, formed, drilled and painted. Steel tube or rod is cut to length to form axles. The handle is stamped, formed, and rolled and then riveted to the front wheel assembly. Plastic wheels are molded, and nylon bushings inserted into the wheel hub. Assembly is most frequently left to the purchaser, so the final production step is packaging of the individual components. Nuts, bolts and sheet metal screws are used in assembling a wagon.

Waste Streams--

Process water is used mainly for plating and cleaning of metal parts. Air emissions result from the painting operations. Solid waste is generated from drilling, cutting, and stamping operations.

Dolls

This segment includes establishments primarily engaged in manufacturing dolls, doll parts, and doll clothing. Establishments primarily engaged in manufacturing stuffed toy animals are also included in this industry. The major products are:

- Animals, stuffed: toy
- Dolls, doll parts, and doll clothing except wigs
- Toys, stuffed.

Dolls were produced by 243 plants, and primary products shipped were valued at $190 million in 1972. Most of these plants (57 percent) employed fewer than 20 workers.

Manufacturing Processes--

The major raw materials include thermoplastics, fabrics, paperboard containers, and metal mill forms. The principal manufacturing operations are

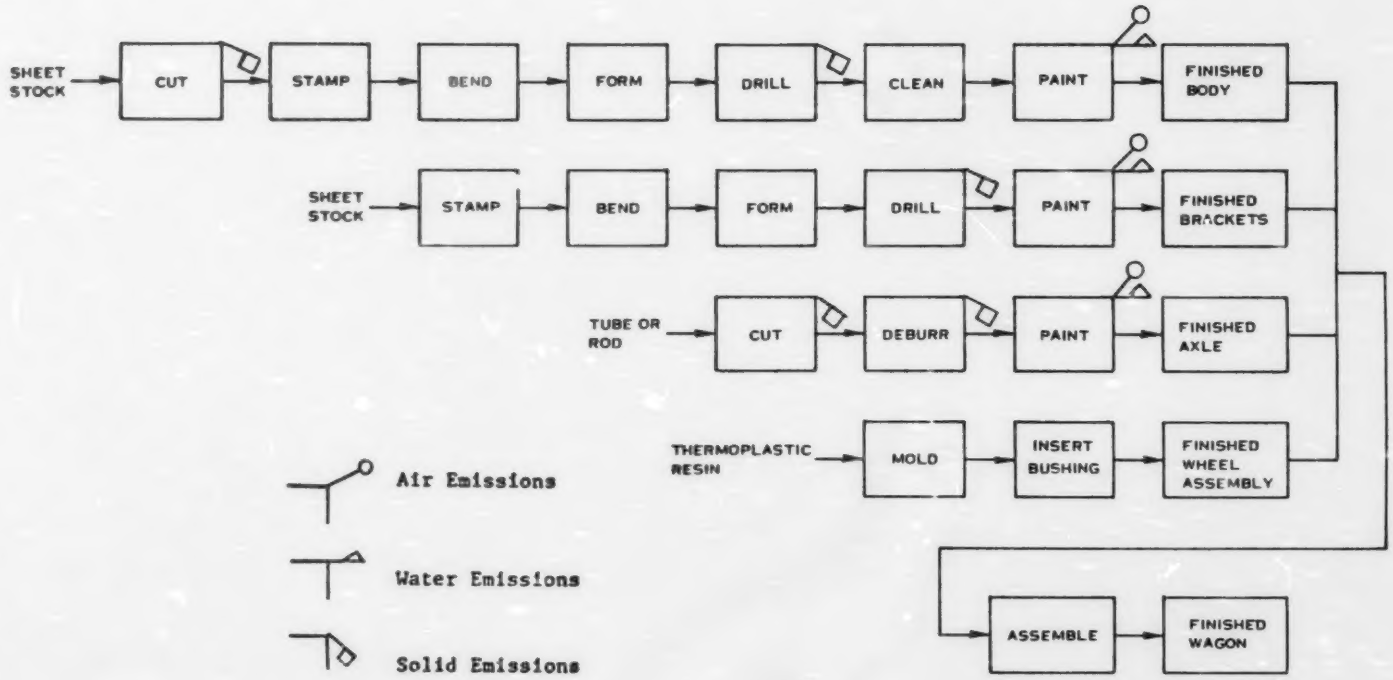

SHEET STOCK
CUT
STAMP
BEND
FORM
DRILL
CLEAN
PAINT
FINISHED BODY
SHEET STOCK
STAMP
BEND
FORM
DRILL
PAINT
FINISHED BRACKETS
TUBE OR ROD
CUT
DEBURR
PAINT
FINISHED AXLE
THERMOPLASTIC RESIN
MOLD
INSERT BUSHING
FINISHED WHEEL ASSEMBLY
ASSEMBLE
FINISHED WAGON
Air Emissions
Water Emissions
Solid Emissions

FIGURE 121. WAGON MANUFACTURING.

plastic molding and assembly operations.

In general, dolls are made by molding and assembling plastic parts, such as heads, arms, legs and trunks, into the finished doll.

The manufacture of dolls, Figure 122 is representative of the doll industry. The various features of the doll, heat, arms, torso, etc., are slush molded. Specific color features for eyebrows, lips, etc., are hot stamped. The plastic parts are then machined and assembled, and the doll is dressed and then packaged for sale. Hair is plastic and clothing is purchased either complete or as already colored material to be made into clothing.

Waste Streams--

Solid wastes are generated from the cutting of the fabric and machining of plastic parts.

Pens, Mechanical Pencils, and Parts

This segment includes establishments primarily engaged in manufacturing pens, pen points, fountain pens, ball point pens, refill cartridges, porous tipped felt tip markers, and parts. The major products are:

- Cartridges, refill: for ball point pens
- Fountain pens and fountain pen desk sets
- Markers, soft tip (felt, fabric, plastic, etc.)
- Meter pens
- Nibs (pen points): gold, steel, or other metal
- Pen points: gold, steel, or other metal
- Pencils and pencil parts, mechanical
- Penholders and parts
- Pens and pen parts: fountain, stylographic and ball point.

Pens and mechanical pencils were produced by 116 plants and primary products shipped were valued at $283 million in 1972. Most of these plants (55 percent) employ more than 20 workers. Over 3 billion pens were produced in the U.S. in 1972.

Manufacturing Processes--

Raw materials are metals (including some exotic metals), plastics, and gum for erasers. The principal manufacturing operations are mechanical

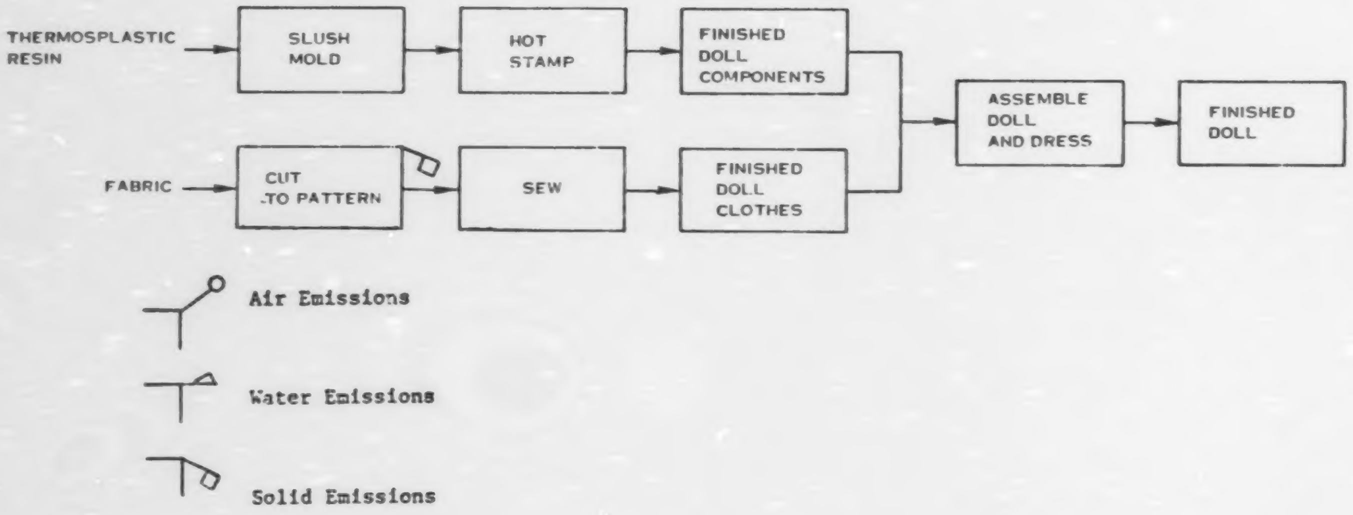

THERMOSPLASTIC RESIN
SLUSH MOLD
HOT STAMP
FINISHED DOLL COMPONENTS
FABRIC
CUT -TO PATTERN
SEW
FINISHED DOLL CLOTHES
ASSEMBLE DOLL AND DRESS
FINISHED DOLL
Air Emissions
Water Emissions
Solid Emissions

FIGURE 122. DOLL MANUFACTURING.

material removal, plastic molding, and assembly operations.

In general, pens and mechanical pencils are made by cutting, stamping, swaging and crimping metals and plastic to form the case to which is added a graphite or ink cartridge.

The manufacture of ball point pens (Figure 123) is representative of the pens and mechanical pencil industry. The case of the pen is slush molded of clear or colored (as desired) plastic. The ink container is a section of extruded plastic tube with a tip assembly installed in one end. The top assembly is the key to the pen's operation and is manufactured by extruding and forming a case (usually brass) in which is installed an iridium ball bearing. A stop is placed behind the base to prevent its slipping out of the case. The plastic ink tube is attached to the tip and filled with ink. Then the tip assembly along with ink tube is installed in the molded case.

Waste Streams--

Process water is used mainly for plating and cleaning, with a minor amount used in metal working along with a lubricating oil. Air emissions result from plating operations.

Sporting and Athletic Goods

This segment includes establishments primarily engaged in manufacturing sporting and athletic goods, not elsewhere classified, such as fishing tackle; golf and tennis goods; baseball, football, basketball, and boxing equipment; roller skates and ice skates; gymnasium and playground equipment; billard and pool tables; and bowling alleys and equipment.

Sporting and athletic goods were produced by 1554 plants, and primary products shipped were valued at $1.454 billion in 1972. Most of these plants (70 percent) employ fewer than 20 workers.

Manufacturing Processes--

A wide range of raw materials are used in the manufacture of sporting goods because of the wide array of finished products. Stock metals, plastics, broadwoven fabrics, and leather are the major raw materials. The principal manufacturing operations are determined by the product and range from casting and molding of plastics to mechanical material removal and material forming of metal.

A wide range of diverse manufacturing processes are used in the sporting and athletic goods industry.

Because of the diversity of products and materials used in the sporting and athletic goods industry, no single product can be considered typical. However, the manufacture of golf clubs and swimming pools are good examples of the type of manufacturing processes used in this industry. Golf club manufacture, as illustrated in Figure 124, starts with the shaft, usually made of steel tubing which is pickled, rinsed, heat treated, drawn, cut,

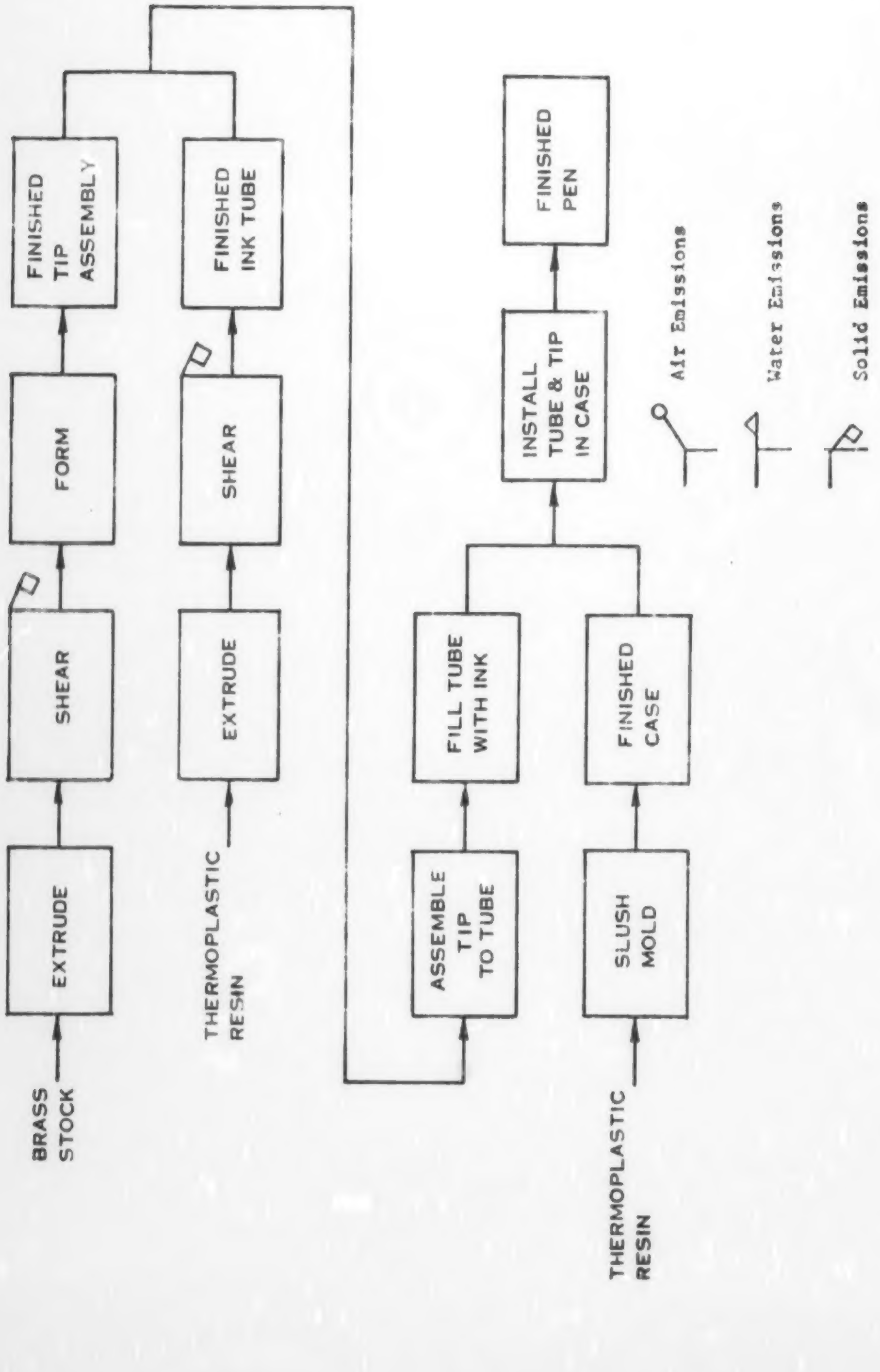

BRASS STOCK
EXTRUDE
SHEAR
FORM
FINISHED TIP ASSEMBLY
THERMOPLASTIC RESIN
EXTRUDE
SHEAR
FINISHED INK TUBE
ASSEMBLE TIP TO TUBE
FILL TUBE WITH INK
THERMOPLASTIC RESIN
SLUSH MOLD
FINISHED CASE
INSTALL TUBE & TIP IN CASE
FINISHED PEN
Air Emissions
Water Emissions
Solid Emissions

FIGURE 123. BALL POINT PEN MANUFACTURING.

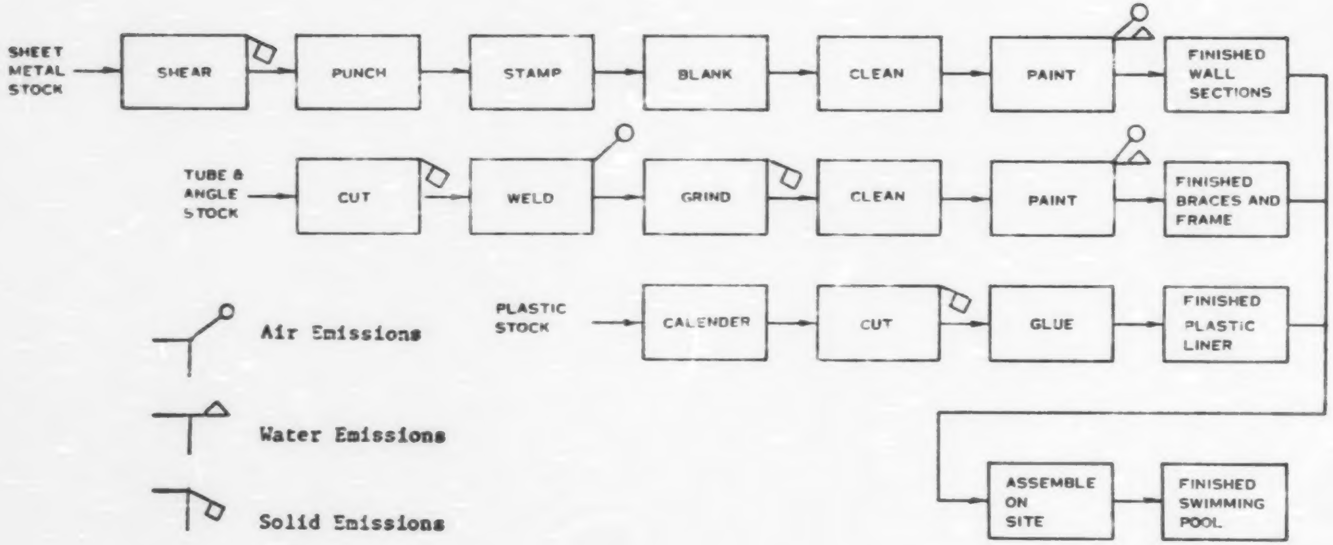

SHEET METAL STOCK
SHEAR
PUNCH
STAMP
BLANK
CLEAN
PAINT
FINISHED WALL SECTIONS
TUBE & ANGLE STOCK
CUT
WELD
GRIND
CLEAN
PAINT
FINISHED BRACES AND FRAME
PLASTIC STOCK
CALENDER
CUT
GLUE
FINISHED PLASTIC LINER
ASSEMBLE ON SITE
FINISHED SWIMMING POOL
Air Emissions
Water Emissions
Solid Emissions

FIGURE 124. SWIMMING POOL MANUFACTURING.

tempered, cleaned, plated, and cleaned again. The metal head of the club is forged or cast and machined. It is then drilled to fit the shaft, heat treated, plated, and cleaned. The head and shaft are joined to form the club, and a handle grip is added. Then it is balanced, polished, inspected, and tested.

Swimming pools (above ground, over 15 foot diameter, metal), as illustrated in Figure 125 are made from various mill forms or sheet metal, usually steel. The wall sections are sheet steel which is sheared, punched, stamped, blanked, cleaned, and painted. The bracing members of the frame work of the pool are built up with angular stock, tubing, and rolled sheet stock. Rolled sheet metal forms the top edge of the pool and all metal parts are painted. The vinyl liner is made by calendering vinyl into a large continuous sheet of the appropriate size for the pool. The liner is a purchased item for many of the pool manufacturers.

Waste Streams--

Process water is used mainly for plating and cleaning at various stages of manufacture of such products as golf clubs, fishing tackle, etc. Air emissions result from the painting, polishing, welding and plating. Solid waste results from the shearing, stamping, machining and drilling operations.

Burial Caskets

This segment includes establishments primarily engaged in manufacturing burial caskets and cases including shipping cases of wood or other material except concrete. Specific products are:

- Burial cases, metal and wood
- Burial vaults, fiber glass
- Casket linings
- Caskets, metal and wood
- Grave vaults, metal.

Caskets were produced by 515 plants, and primary products shipped were valued at $382 million in 1972. Most of these plants (64 percent) employed fewer than 20 workers. Metal caskets comprise almost half of the production and over half of the dollar value of this industry. Wood and other types of caskets account for the remainder of the production in this industry.

Manufacturing Processes--

Metal mill forms, wood, fiber glass, and fittings are the major raw materials. The principal manufacturing operations are material forming, mechanical material removal, assembly operations and material coating.

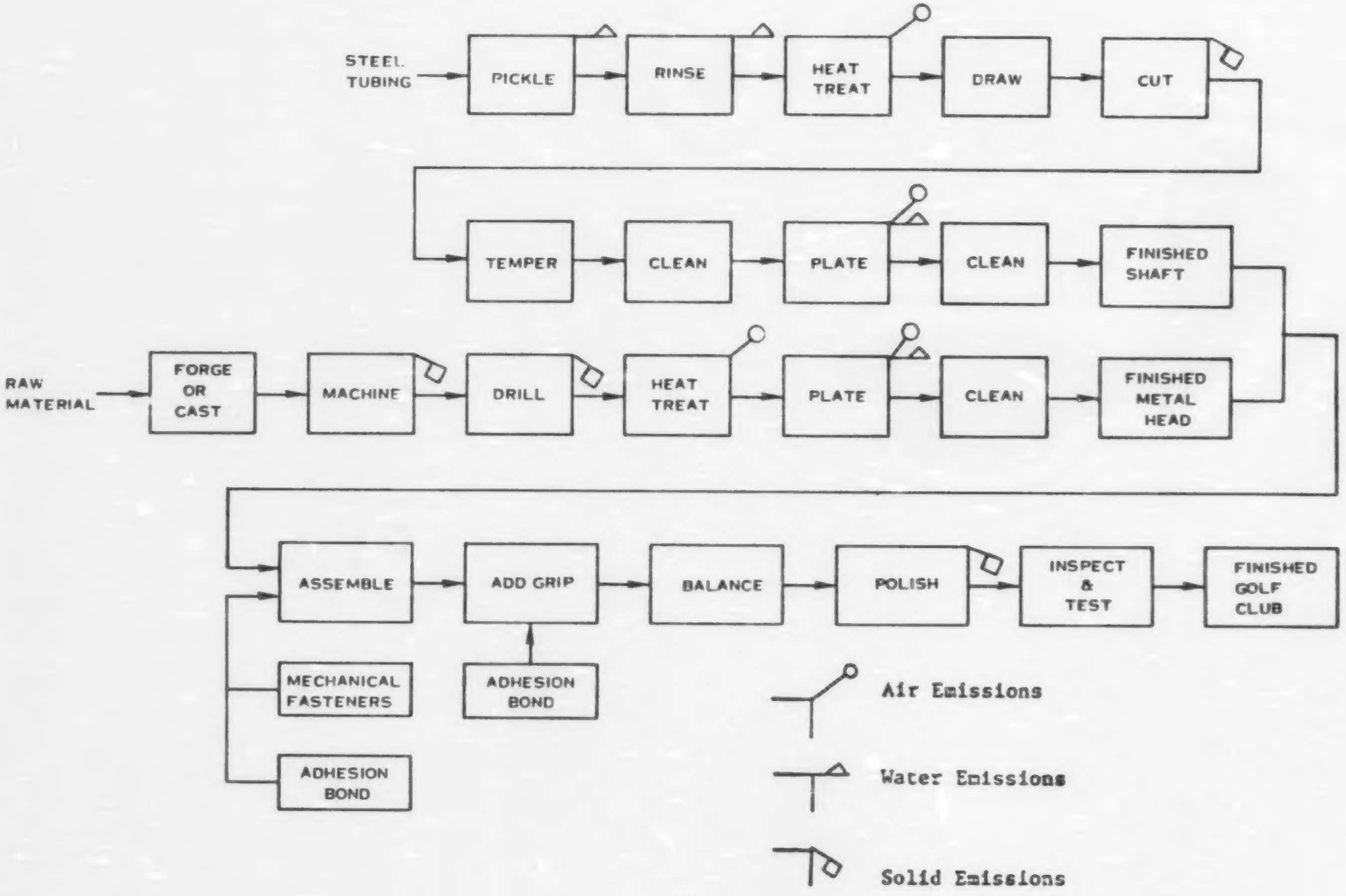

STEEL TUBING
PICKLE
RINSE
HEAT TREAT
DRAW
CUT
TEMPER
CLEAN
PLATE
CLEAN
FINISHED SHAFT
RAW MATERIAL
FORGE OR CAST
MACHINE
DRILL
HEAT TREAT
PLATE
CLEAN
FINISHED METAL HEAD
ASSEMBLE
ADD GRIP
BALANCE
POLISH
INSPECT & TEST
FINISHED GOLF CLUB
MECHANICAL FASTENERS
ADHESION BOND
ADHESION BOND
Air Emissions
Water Emissions
Solid Emissions

FIGURE 125. GOLF CLUB MANUFACTURING.

In general, caskets are made by cutting the pieces of the shell and then forming these pieces. These shell pieces are then joined to form the completed casket shell and plated. Casket linings of cloth material are next placed inside the casket shell. Hardware such as handles and ornamentation can be cast, forged or rolled to the desired shape or form and then plated to finish the piece.

The manufacture of a metal casket shell (Figure 126) is representative of the casket industry. First, the sides, ends, bottom, and cover are stamped from sheet stock and then formed to their final shapes. The shell is then assembled and the seams welded. The cover and shell are pickled and plated. Frequently epoxy is applied by a dipping process. For preservation, the cover is attached to the shell with hinges and the interior is fitted and decorated as desired.

Waste Streams--

Process water is used mainly for plating and cleaning operations. Air emissions result from the plating, and painting operations and from welding. Solid waste is generated by grinding operations.

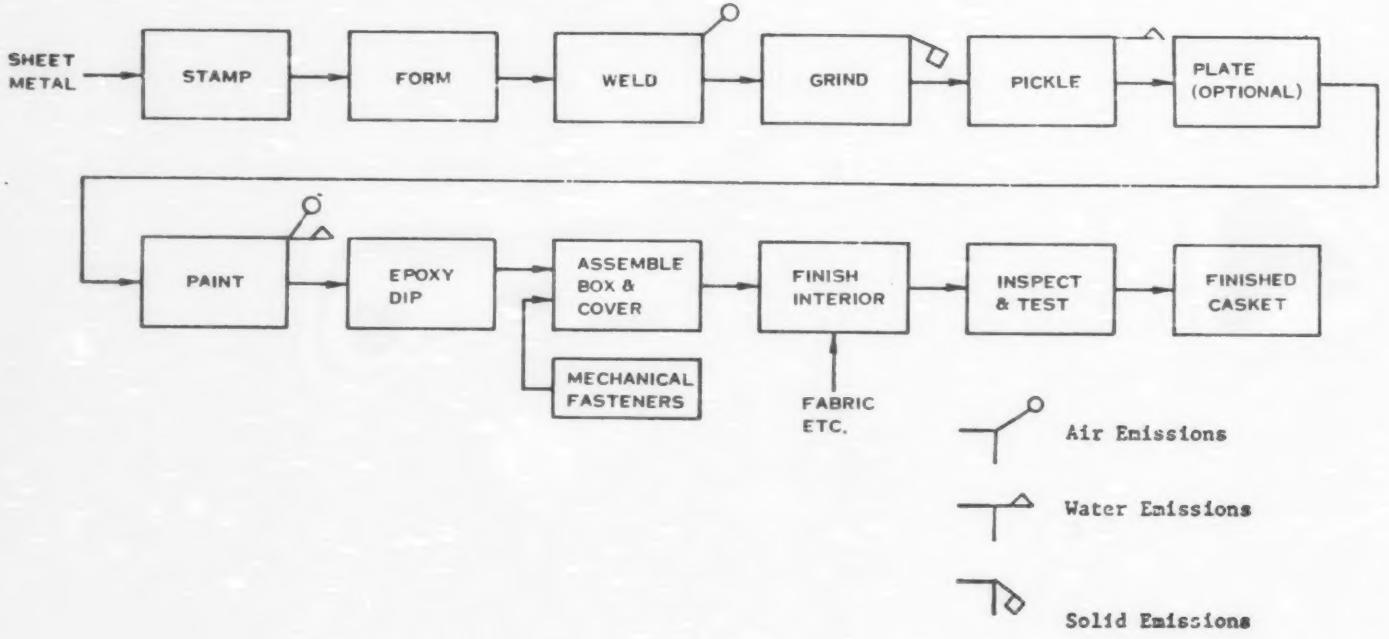

SHEET METAL
STAMP
FORM
WELD
GRIND
PICKLE
PLATE (OPTIONAL)
PAINT
EPOXY DIP
ASSEMBLE BOX & COVER
MECHANICAL FASTENERS
FINISH INTERIOR
FABRIC ETC.
INSPECT & TEST
FINISHED CASKET
Air Emissions
Water Emissions
Solid Emissions

FIGURE 126. BURIAL CASKETS MANUFACTURING.

SECTION 6

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APPENDIX

The assigned SIC codes for the subject report all covered a number of industries as they are defined by the SIC Manual. For purposes of analyses of environmental impacts the products in each category were examined to determine whether they seemed to be good approximations of real world industries which could be defined in terms of populations of companies competitively engaged in the production of similar products using similar input materials and the same kinds of unit processes and unit operations. For the categories examined there appeared to be a reasonable degree of correspondence between some SIC category and industries as they are operating in commercial practice. Because of the number and complexity of the industries covered by the study it was necessary to use readily available information and exercise considerable judgement in defining "industries" to be used as a basis for further investigation. It is felt however, that this list which has been developed is a reasonable starting point for further study of the industries under consideration.

The table which follows presents the industries identified for each assigned SIC category. The industries identified are all equatable to 4-digit codes (industries), 5-digit codes (product groups) or 7-digit codes (products) as defined by the Census of Manufactures. The titles as shown in the table may or may not correspond with SIC titles. The associated SIC code numbers in the table do however identify products which have been taken to represent the product slate for the identified industry. The dollar value of shipments for the SIC categories associated with each defined industry is shown to provide a rough index of the relative economic importance for each industry. Further information on what products are included in each industry is available from the Census of Manufactures.

It should be noted that all subdivisions of every assigned SIC category have not been covered in the industries identified. In some categories, especially those involving "Miscellaneous Products" or products "not elsewhere classified", small categories which are not catalogable as compounded or fabricated products or which were not considered of sufficient importance from the standpoint of economic importance or potential for environmental impact were dropped out. Despite this, a very high percentage of the products included, judged in terms of value of shipments, have been accounted for.

The extent to which industry and product statistics may be matched with each other is measured by two ratios. The first of these ratios, called primary specialization ratio, measures the proportion of product shipment (both primary and secondary) of establishments classified in the industry to total shipments of such products by all manufacturing establishments. The second ratio, defined as coverage ratio, is the proportion of primary products shipped by the establishments classified in the industry to total shipments of such products by all manufacturing firms.

It should be further noted that the table of industries has all assigned SIC categories arranged in numerical order. The subgroups shown under each assigned category are not in all instances those normally included subgroups. Some defined industries equatable to SIC groups outside of the assigned categories have been included where it seemed logical to do so. Where this was done a note of explanation is identified.

Finally it should be stated that the value of shipment data shown are taken directly from the 1972 Census of Manufactures. For each principal product the value of primary product shipments made in all industries was used. While this is probably not of great importance to the intended use of the data, the Census of Manufactures should be consulted by readers who wish to understand how the data were collected.

Table A-1. LISTING OF INDUSTRIES IDENTIFIED FROM ASSIGNED SIC CATEGORIES

Industries Identified From Assigned SIC Categories	SIC Code(s) Included	Value of Shipments (Millions of $)	Notes
SIC Group 245			
Mobile homes	2451	3190	(1)
Prefabricated wood buildings	2452	1001	
SIC Major Group 25			
Wood household furniture	2511	2716	
Upholstered furniture	2512	1990	
Metal household furniture	2514	859	
Mattresses and bedsprings	2515	1079	
Wood TV and radio cabinets	2517	283	
Wood office furniture	2521	259	
Metal office furniture	2522	781	
Public building and related furniture	2531	496	
Wood partition and fixtures	2541	772	
Metal partitions and fixtures	2542	713	
Drapery hardware blinds and shades	2591	311	
SIC Group 264			
Coated printing paper	26411	111	(2)
Waxed paper	26412	153	
Laminated or coated rolls and sheets	26417	356	
Gummed products	26413	139	
Pressure sensitive tape	26414	574	
Commercial envelopes	2642	588	(3)
Grocers and variety bags	26431	513	
Specialty bags and liners	26432	819	
Shipping sacks and multi-wall bags	26433	408	
Office supplies	26451	342	
Pressed and molded pulp goods	26462	136	

Table A-1 (continued)

Industries Identified From Assigned SIC Categories	SIC Code(s) Included	Value of Shipments (Millions of $)	Notes
SIC Group 264 (continued)			
Sanitary napkins and tampons	26471	281	
Sanitary tissue health products	26472	1692	
Stationary	26481	118	
Tablets and related products	26482	219	
Wrapping paper (gift wrapping etc)	26492	181	
Wall paper	26493	83	
SIC Group 265			
Folding paperboard boxes	2651	1372	
Setup paperboard boxes	2652	342	
Corregated and solid fiber boxes	2653	4196	
Sanitary food containers	2654	1381	
Fiber cans, drums and related products	2655	620	
SIC Major Group 27			
Newspapers	2711	7908	
Periodicals	2721	3197	
Book printing	2731	1049	
Commercial printing (letterpress)	2751	3404	
Commercial printing (lithographic)	2752	4919	
Engraving and plate printing	2753	205	
Commercial printing (gravure)	2754	759	
Manifold business forms	2761	1381	
Greeting card publication	2771	583	
Blank books, looseleaf binders	2782	566	
Bookbinding	2789	369	
Typesetting	2791	508	
Photoengraving	2793	321	
Electrotyping and stereotyping	2794	35	
Lithographic platemaking	2795	263	
SIC Group 284			
Soap and other detergents	2841	2851	

Table A-1 (Continued)

Industries Identified From Assigned SIC Categories	SIC Code(s) Included	Value of Shipments (Millions of $)	Notes
SIC Group 284 (continued)			
Polishes and sanitation goods	2842	1735	
Surface active agents	2843	580	
Toilet preparations	2844	4247	
SIC Group 285			
Paint and allied products	2851	3520	
SIC Group 289			
Natural base glues and adhesives	28913	119	
Synthetic resin and rubber adhesives	28914	671	
Caulking compounds and sealants	28915	121	
Printing ink	2893	498	
Fireworks and pyrotechnics	2899529	39	(4)
SIC Group 295			
Paving mixtures and blocks	2951	893	
Asphalt felts and coatings	2952	902	
Bituminous fiber pipe	26461	21	(5)
SIC Major Group 30			
Tires and inner tubes	3011	4898	
Plastic and rubber footwear	3021	493	
Reclaimed rubber	3031	52	
Rubber and plastic hose and belting	3041	886	
Sponge and foam rubber goods	30693	350	
Rubber floor and wall coverings	30694	98	
Hard rubber mechanical goods	30695 11,15,18	98	(6)
Molded rubber mechanical goods	30695 21,23,25, 29	629	
Rubber soles and heels	30696	154	
Druggists and medicalrubber goods	30697	116	
Retread tires	7534		(7)
SIC Group 31			
Boot and shoe cut stock	3131	196	

Table A-1 (Continued)

Industries Identified From Assigned SIC Categories	SIC Code(s) Included	Value of Shipments (Millions of $)	Notes
SIC Group 31 (continued)			
Slippers	3142	159	
Shoes (mens, womens and childrens)	3143,3144, 3149	2965	(8)
Luggage	3161	321	
Personal leather goods	3151,3171, 3172	654	(8)
SIC Group 323			
Mirrors	32315	254	
Tempered glass	32316, 81,83	153	(9)
Laminated glass	32113	534	(10)
Scientific and industrial glassware	32316 38	156	(11)
SIC Group 327			
Concrete block and brick	3271	795	
Concrete and other precast construction products	32721,32722, 32723	1517	
Ready-mixed concrete	3273	3578	
SIC Group 328			
Cut stone and stone products	3281	286	
SIC Group 329			
Abrasive products	3291	892	
Asbestos products	3292	742	
Gaskets, packing and sealing devices			
Mineral wool products	3296	391	
SIC Major Group 34			
Metal cans	3411	4224	
Metal shipping containers	3412	509	
Kitchen and table cutlery	34211	183	(12)
Scissors and shears	34212		
Blade razors and blades	34212	207	
Handtools	3423,3425	1315	
Furniture hardware	34292	205	

Table A-1 (Continued)

Industries Identified From Assigned SIC Categories	SIC Code(s) Included	Value of Shipments (Millions of $)	Notes
SIC Major Group 34 (continued)			
Insulated bottles, jugs and chests	34293	85	
Binders hardware	34294	928	
Plumbing fixtures	3431	315	
Plumbing fittings and brass goods	3432	673	
Hot water and steam heating systems	34333,34335	220	
Prefabricated structural metal	3441	3305	
Metal doors sash and trim	3442	1902	
Fabricated platework (boiler shops)	3443	3265	
Sheet metalwork	3444	2650	
Architectural metalwork	3446	589	
Prefabricated metal buildings	3448	578	
Reinforcing rods and other metal construction products	34494,34495	856	
Screw machine products	3451	1083	
Bolts, nuts, rivets, washers	3452	1988	
"Custom" iron and steel forgings	3462	1838	
"Custom" non-ferrous forgings	3463	280	
Stamped metal parts	3465,3469	7739	(13)
Crowns and closures	3466	339	
"Custom" plating and polishing	3471	1008	(14)
Metal coatings (organic)	34790,61,71,81	351	(14)
Small arms and ammunition	3482,3484	756	
Military arms and ammunition	3483,3489	1757	
Coil and leaf springs	3493	361	
Valve and pipe fittings	3494	2876	
Wire products	3495,3496	3448	
SIC Major Group 35			
Turbine and tubrine generator sets	3511	2079	
Stationary internal combustion diesel engines	35193	604	

Table A-1 (Continued)

Industries Identified From Assigned SIC Categories	SIC Code(s) Included	Value of Shipments (Millions of $)	Notes
SIC Major Group 35 (continued)			
Stationary internal combustion gasoline engines	35191,35192	450	
Outboard motor	35195	425	
Diesel engines for buses and trucks	35194	634	(15)
Farm machinery and equipment	3523	4143	
Lawn and garden equipment	3524	1143	
Construction equipment	3531	5653	
Mining equipment	3532	729	
Oil field equipment	3533	980	
Elevators and moving stairs	3534	412	
Conveyors and conveyor equipment	3535	825	
Hoists, cranes and monorails	3536	446	
Industrial trucks and tractors	3537	1004	
Machine tools - metal cutting	3541	1258	
Machine tools - metal forming	3542	670	
Special dies, tools, jigs and fixtures	3544	2713	
Machine tools accessories	3545	1151	
Power driven handtools	3546	622	
Rolling mill machinery	3547	247	
Welding and cutting apparatus	35493	93	
Automotive maintenance equipment	35494 11	111	
Food products machinery	3551	867	
Textile machinery	3552	738	
Woodworking machinery	3553	411	
Paper industries machinery	3554	381	
Printing trades machinery	3555	736	
Chemical manufacturing machinery	3559 11	212	
Foundry equipment and equipment	35592	132	
Plastic working machinery	35593	434	
Rubber-working machinery	35594	137	

Table A-1 (Continued)

Industries Identified from Assigned SIC Categories	SIC Code(s) Included	Value of Shipments (Millions of $)	Notes
Pumps and pumping equipment	3561	1632	
Ball and roller bearings	3562	1418	
Air and gas compressors	3563	722	
Blowers and fans	3564	682	
Industrial patterns	3565	234	
Typewriters	3567	1046	(16)
Electronic computers	3573	6108	
Calculating and accounting machines	3574	694	
Scales and balances	3576	182	
Duplicating machines and photo copying equipment	3579	1046	(16)
Automatic merchandising machines	3581	306	
Commercial laundry equipment	3582	183	
Industrial and commercial AC and heating	35851,35852, 35853,35854, 35857	4867	(17)
Room A.C. and dehumidification	35856	679	
Warm air furnaces	35858	384	
Measuring and dispensing pumps	3586	183	
Commercial cooking and cleaning equipment	3589	864	
Carburetor, pistons, rings, and valves	3592	791	
SIC Major Group 36			
Transformers	3612	1436	
Switchgear and switchboard apparatus	3613	2058	
Motor and generators	3621	2635	
Industrial controls	3622	1245	
Welding apparatus, electric	3623	570	
Carbon and graphite products	3624	335	
Capacitors	36291	112	
Retifying apparatus	36292	132	

Table A-1 (Continued)

Industries Identified from Assigned SIC Categories	SIC Code(s) Included	Value of Shipments (Millions of $)	Notes
Household cooking equipment	3631	1027	
Household refrigerators, home and farm freezers	3632	1419	
Household laundry equipment	3633	1289	
Electric housewares and fans	3634	1448	
Household vacuum cleaners	3635	439	
Sewing machines	3636	152	
Household water heaters	36391	119	
Dishwashing machines	36394 12,14	359	
Food waste disposal units	36394 71	66	
Electric lamps	3641	1089	
Current carrying wiring devices	3643	1206	
Non current carrying wiring devices	3644	832	
Residential electric lighting fixtures	3645	746	
Commercial, industrial and institutional electric light fixtures	3646	701	
Vehicular light equipment	3647	358	
Radio and television receiving sets	3651	3608	
Phonograph records and recorded tapes	3652	537	
Telephone and telegraph apparatus	3661	3973	
Radio and television transmitting equipment	3661	8376	(18)
Radio and television receiving electron tubes	3671	189	
Cathode ray television picture tube	3672	633	
Transmitting, industrial and special purpose electron tubes	3673	366	
Semiconductors and related devices	3674	2360	
Electronic capacitors	3675	454	
Resistors for electronic application	3676	438	
Electronic coils	3677	385	
Connectors, for electronic applications	3678	523	

Table A-1 (continued)

Industries Identified from Assigned SIC Categories	SIC Code(s) Included	Value of Shipments (Millions of $)	Notes
SIC Group 36 (Continued)			
Storage battage	3691	952	
Primary battery dry, wet	3692	316	
X-ray apparatus and tubes	3693	383	
Electrical equipment for internal combustion engines	3694	1781	
Lamp bulb components	36992	332	
Appliance wire and cord	36996	366	
SIC Major Group 37			
Motor vehicles	3711	41045	
Truck and bus bodies	3713	1444	
Motor vehicle parts and accessories	3714	19417	
Truck trailer	3715	1079	
Aircraft	3721	7538	
Aircraft engines and engine parts	3724	3069	
Air parts and auxilliary equipment	3728	3436	
Ship building and repairing	3731	3200	
Boat building and repairing	3732	1031	
Railroad equipment	3743	2284	
Bicycles and parts	37511	396	
Motorcycles and parts	37512	112	
Guided missiles and space vehicles	3761	3705	
Space propulsion units and parts	3764	740	
Guided missiles and space vehicle parts and auxillary parts	3769	825	
Travel trailers and campers	3792	1276	
Tanks and tank components	3795	285	
SIC Major Group 38			
Engineering and scientific instruments	3811	1106	
Building interior environmental controls	3822	658	
Process control instruments	3823	794	

Table A-1 (Continued)

Industries Identified from Assigned SIC Categories	SIC Code(s) Included	Value of Shipments (Millions of $)	Notes
SIC Major Group 38 (continued)			
Fluid meters and counting devices	3824	327	
Instruments to measure electricity	3825	1329	
Measuring and controlling devices	3829	585	
Optical instruments and lenses	3832	584	
Surgical and medical instruments	3841	984	
Surgical appliances and supplies	3842	1142	
Dental equipment and supplies	3843	352	
Ophthalmic goods	3851	483	
Still picture equipment	38611	616	
Sensitized photographic film and plates	38616,38619, 38615,38617	2406	
Prepared photographic chemicals	38618 11	286	
Photo copying equipment	38612	1455	
Motion picture equipment	38613	191	
Clocks	38731	329	
Watch cases	38737	52	
Watches	38734,38735	477	
SIC Major Group 39			
Jewelry precious metal	3911	981	
Silverware and plateware	3814	317	
Jewelers materials and lapidary work	3915	336	
Musical instruments	3931	525	
Dolls	3942	277	
Games and toys	39441,39442	1214	
Bicycles childrens vehicles	3944	126	
Sporting and athletic goods	3949	1538	
Pens and mechanical pencils	3951	311	
Lead pencils and art goods	3952	174	
Marking devices	3953	163	
Carbon paper and inked ribbon	3955	317	

Table A-1 (Continued)

Industries Identified from Assigned SIC Categories	SIC Code(s) Included	Value of Shipments (Millions of $)	Notes
SIC Major Group 39 (Continued)			
Costume jewelry	3961	441	
Artificial flowers	3962	101	
Buttons	3963	100	
Needles, pins, fasteners	3964	553	
Brooms and brushes	3991	391	
Signs and advertising displays	3993	1098	
Burial caskets	3995	387	
Hard surface floor covering	3996	300	
Chemical fire extinguishing equipment	39991	125	
Matches	39993		

Notes:

(1) Does not include recreational vehicles. See SIC 3792 travel trailers and campers.

(2) Classification of industries included under SIC Group 264 is considered more speculative than most other industries because of difficulty in interpretation of product descriptions.

(3) Includes all types of envelopes except stationary which is covered under SIC Product Group 26481.

(4) Fireworks and pyrotechnics represent group of minor economic importance under SIC Industry 2899 which by its nature is considered worthy of environmental assessment.

(5) Bituminous fiber pipe (SIC Product Group 26461) is listed under SIC Group 295 with industries involving use of asphalt binders.

(6) Hard rubber mechanical goods and molded mechanical goods may have more environmental significance than other products under miscellaneous category.

(7) Retread tires, included under service industries in SIC system is felt to present problems similar to those of other industries being d under considered under SIC major group 30. Since retread tires are considered to be a non-manufacturing industry by the Census of Manufactures there is no value of shipment data reported.

(8) Data on shoe industries and personal leather goods were not adequate to determine with confidence whether shoe manufacture represented one or more industries. For present purposes it has been considered a single industry.

(9) Sales data for some species of tempered glass were not available. Total shown is reported figure for reported categories.

(10) Laminated glass is manufactured by companies in the glass industry and from purchased glass. Division in terms of volume is not known.

(11) Scientific and industrial glassware volume of sales are reported only as part of a larger group.

(12) SIC category 34211 contains a collection of products roughly divisible as shown, which probably come from a number of different industries.

(13) All stamped metal parts (automotive and other) have been combined for analysis as one industry.

(14) Custom plating and polishing and "metal coatings (organics)" have been defined as industries for further investigation of possible environmental impacts which will not appear in other categories.

(15) Dual-fuel engines are included with diesel engines.

(16) Separate data could not be published for industry 3572 typewriters, without revealing the operations of individual companies. Accordingly industry 3572 typewriters has been combined with industry 3579, office machines, n.e.c. for 1972.

(17) The total value of shipments of refrigeration machinery includes extensive duplication resulting from the use of products of some establishments in the industry as materials by others within the same industry.

(18) This category includes a wide variety of transmission equipment including alarm systems, military equipment, etc.